POWER

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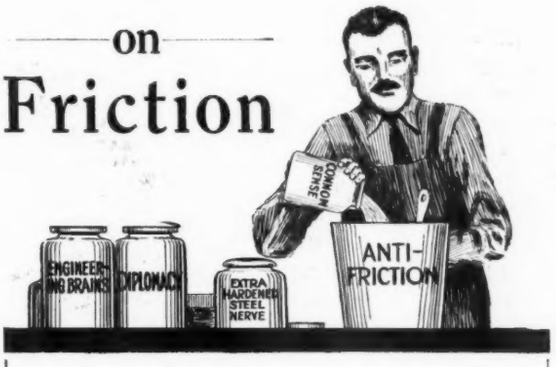
HELPFUL HINTS



In a Power Plant let us admit that there are three kinds of friction:

Political

The workings of a man or body of men to get you out and the other fellow in. Very troublesome and often serious.

Managerial

The unnecessary work the engineer in charge has to do in order to get the required tools and appliances to properly operate the plant. Extremely common, always serious.

Mechanical

Each of the above contributes its influence to hampering reliability, efficiency and economy in power-plant operation. With political friction there can be no discipline of the force. With managerial friction, the engineer is powerless.

LET US remove the political friction first. How? Careful now! Open your *private* kit of tools and take out a can of diplomacy. (Don't use "soft soap": it gums up the bearings.) Then a large, well-tempered piece of extra-hardened steel nerve. (Don't use the bottled kind; it may cause you to lose your self-respect.) Then mix with a good supply of common sense. (Don't try to use so-called "horse sense." Horses haven't any sense, otherwise there'd be more funerals.) Mix these ingredients thoroughly and apply to afflicted parts, absolutely fearlessly. This is a guaranteed cure for all political friction.

Now, the managerial: Use the first two ingredients, only the piece of steel nerve had best be smaller; then take an extra large portion of engineering brains (Don't use common sense here, but brains, real true engineering brains,) and apply this mixture judiciously where needed. This mixture is very rich and powerful. Watch carefully the safety valve. We must not have any explosions.

Now, remove the mechanical friction. How? Simply by using the tools and accessories you secured when you overcame the managerial friction.

Well, say! If you did not get *all* requisite appliances to do this work, this aggravating friction still exists, so "go to it again", using, if absolutely required, a little more high-grade steel nerve, but mix it thoroughly with diplomacy and engineering brains. The force is on your side, political friction being removed. The old man is on your side because he sees that you're "on to your job."

Mechanical friction of any kind, grade size, shape, class, cause, effect or amount of each or all is "easy" now —"dead easy".

Read this over again carefully

Contributed by H. W. JONES, *Chicago, Ill.*

Modernizing Narragansett Co.'s South Street Station

By Charles H. Bromley

SYNOPSIS—A large reciprocating-engine central station is completely converted into a modern turbo-generating plant, buildings and all, without interrupting service. The electrical system is likewise changed. Jet condensers are used, and excess exhaust steam is automatically admitted to the low-pressure stages of one of the large turbines. Three ways are provided for getting coal into the bunkers.

The Narragansett Electric Lighting Co. is one of the oldest lighting companies in New England, as well as one of the foremost. A study of its South Street station, Fig. 1, as it is today, new and thoroughly modern compared to the old station, illustrates how fast changes must be made to keep pace with the strides in the generation and distribution of electric current.

Providence being in the heart of an area of approximately 130 sq.mi., having a population of over four hundred thousand and caring for a large industrial and commercial business, it is an ideal place for central-station development. During the last year the average load has increased 33 per cent. The Brown & Sharpe Manufacturing Co. depends upon the Narragansett company for its entire power supply.

Six power engineers connected with the sales department are available to make investigation of any isolated plant, furnishing a report on operating costs as they find them, and as they would be with the Narragansett company's power. The service of these engineers is gratis.

The Old Station and Its Equipment

It was not many years ago that this station was pointed to as representing the top notch of engineering practice. Today finds a new plant in place of the old, one of greater capacity and thoroughly modern, the transformation having been accomplished without any interruption to normal service or operating conditions. The change was made by the Narragansett company's engineers.

The old station had 10 cross-compound condensing Corliss engines: Six of 750 hp., three of 1,500 hp., and one of 1,800 hp.—a total of 10,000 hp. or, say 7,400 kw. Today there is available 41,000 kw. in six units (five turbines and the 1,800-hp. engine) including the 20,000-kw. which has recently been tied in.

The two 1,500-hp. and the 1,800-hp. units in the old station were belted to a long shaft to which were also belted many arc dynamos located above the main drive shaft. The old switchboard, though simple and one of the finest of its time, has been replaced by a new board of the latest design.

The engineering department was confronted with the problem of converting this old plant into a modern turbo-generating station, necessitating many changes in buildings, stacks, equipment, aërial and underground distributing systems, substations, etc., and yet giving uninterrupted service during construction changes. Fig. 2 is an unusual view, showing the steelwork of the main part of the new station. Additional steaming capacity was necessary as some of the old boilers were unfit for any but emergency needs, and this caused the others to be kept in such constant service that little time was available to care for them. In the old boiler house there were twenty water-tube boilers, fitted with mechanical stokers, which averaged 400 hp. each. Sixteen of these

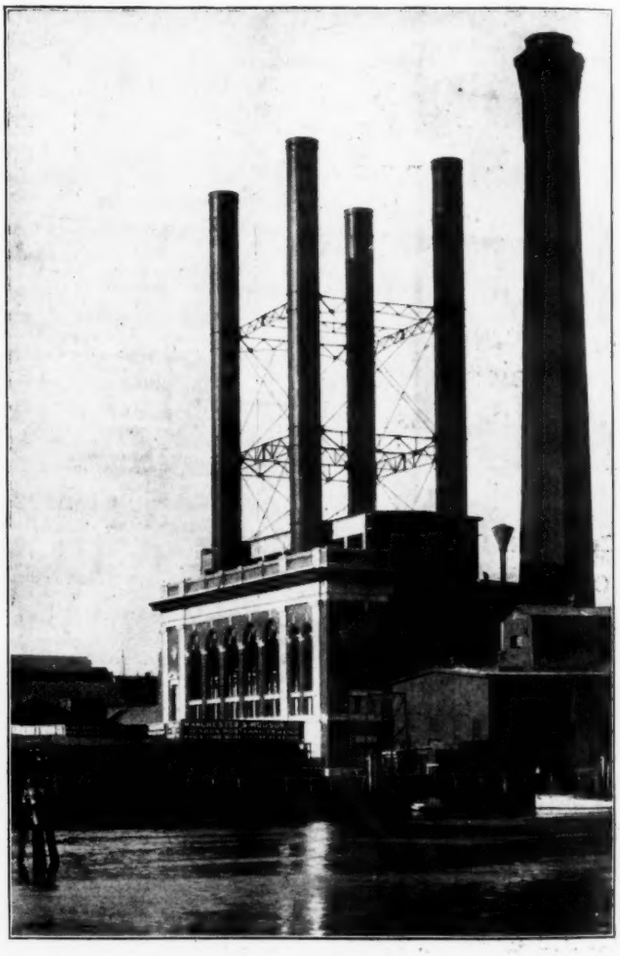


FIG. 1. THE STATION VIEWED FROM THE RIVER

were abandoned and four, fitted with new drums for additional capacity, have been reset in the new building.

The new boiler house contains ten 600-hp. Babcock & Wilcox water-tube boilers, besides the four old ones mentioned. As all are capable of operating continuously at 200 per cent. builders' rating, a total capacity of about 16,000 hp. is available for ordinary demands, with an additional 100-per cent. normal rating for emergencies at peak loads, which high rating has been successfully carried for short periods.

All boilers are fitted with 7-retort extension-grate underfeed stokers driven by four 5¼x6-in. vertical engines

through silent chains. It may be interesting to note that these engines are operating satisfactorily without cylinder oil, the exhaust steam being used for feed-water heating. The whole arrangement is easily adjusted and is compact. A main driving shaft on each side of the firing aisle, driven by two engines, sectionalized by quills and couplings, makes a neat and flexible system. Being

may be controlled readily by water jets in the superheater-inlet manifolds. The supply coming from the hot feed water gives a considerable range for fluctuation without readjustment. This is shown in Fig. 3.

Top uptakes on all boilers, while uncommon, have been applied satisfactorily. Also placing the first baffle directly over the bridge-wall is unusual. This in con-

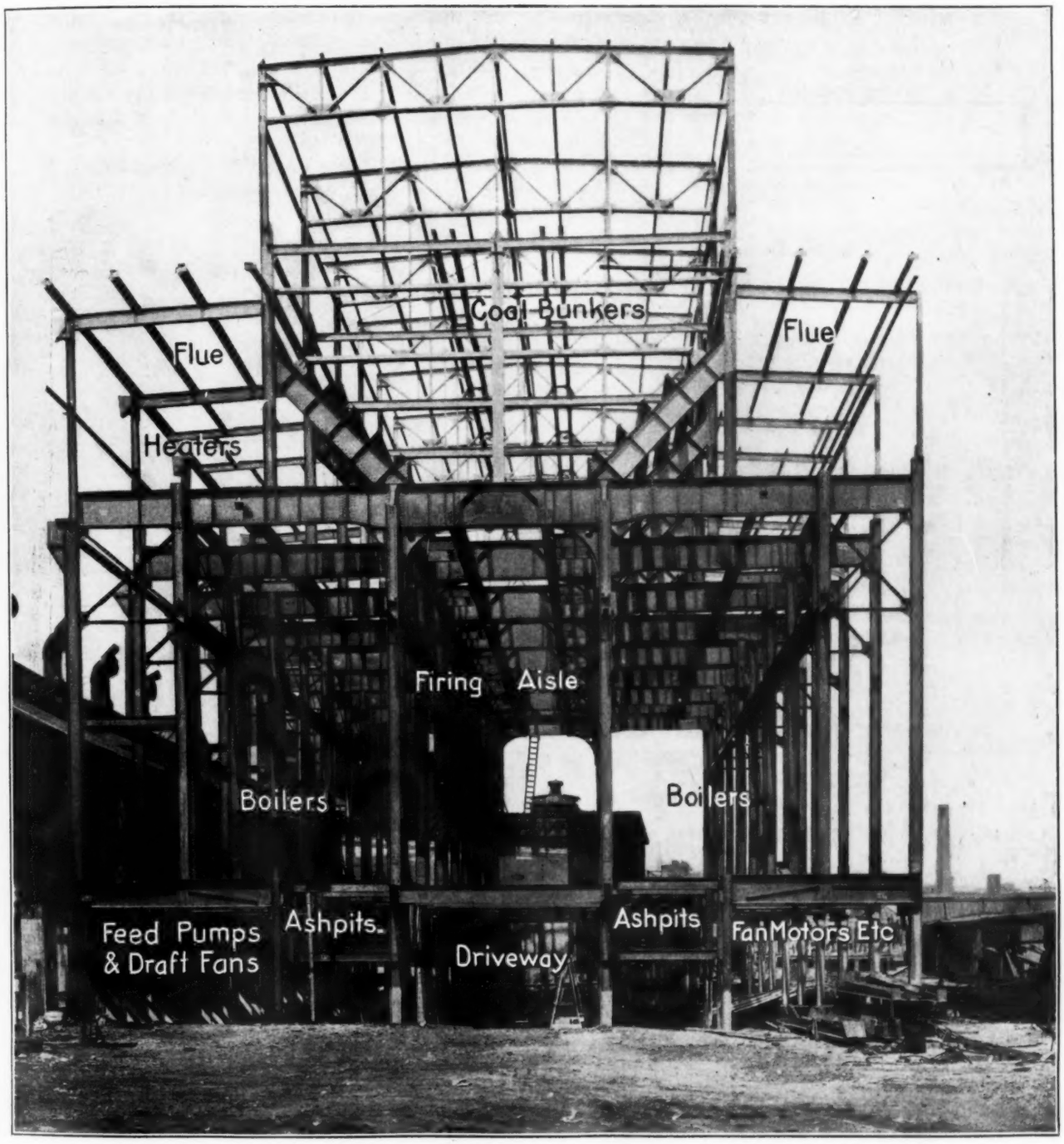


FIG. 2. AN UNUSUAL PICTURE, SHOWING ALL OF THE STEELWORK OF THE PLANT

concealed under the floor as well as protected below from dust and dirt, its life is prolonged.

The steam leads from the boilers are 8 in., exceptionally large to allow for judicious forcing, the working conditions being 200 lb. steam pressure with 100 deg. F. superheat. Superheaters with 8-in. manifolds and 2-in. elements are used. If occasion requires, the superheat

junction with the uptakes, necessitated shortening both the second and third passes, but no ill effects followed. At 165 per cent. rating the temperature difference between the third pass and the base of the stack (almost immediately over the drums) was 50 deg. F. At 200 per cent. rating this difference was 76 deg. F., and at 300 per cent. it was approximately 100 deg. F. Not tak-

ing into consideration the figure for 300 per cent., a fair average would be 60 deg. drop of temperature during the passage of the gases around the drums to the uptake. This is a gain in temperature that would be lost if the gases passed out at the rear as is usual.

Assume a 60-deg. drop for 200 per cent. rating. Then for each 600-hp. boiler we have an output of

$$1{,}200 \times 34.5 = 41{,}400 \textit{ lb. of steam per hr.}$$

An evaporation of 8½ lb. of water per pound of coal is

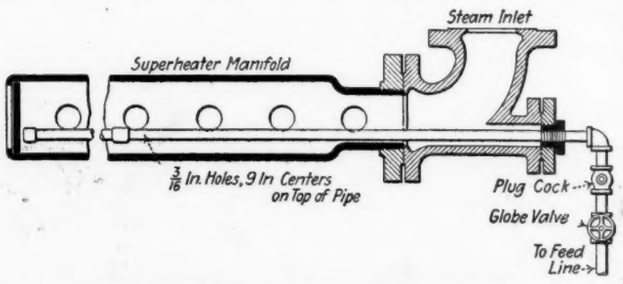


FIG. 3. SUPERHEATER MANIFOLD, SHOWING WATER JET PIPE TO CONTROL SUPERHEAT

fair, so the coal consumption at 200 per cent. rating is

$$\frac{41{,}400}{8.5} = 4{,}870.6 \textit{ lb. of coal per hr.}$$

Assume 16 lb. of flue gas per pound of coal. Then

$$4{,}870.6 \times 16 = 77{,}930 \textit{ lb. of flue gas per hr.}$$

The specific heat of flue gas is ordinarily taken as 0.024;

Air for the furnaces is first discharged from the generators, at about 120 deg. F., into the engine-room basement, then forced into the stoker wind boxes by three 60,000-cu.ft. turbine-driven and two motor-driven 42,000-cu.ft. blowers. By changing over from turbine-driven to motor-driven fans as the load conditions demand, the heat balance of the station may be controlled to advantage. The main air duct, as well as all leads to and from it, is overhead, which leaves all the basement clear for ash handling. As the fans, the dampers and the stoker engines are automatically controlled, hand regulation for combustion purposes is reduced to a minimum.

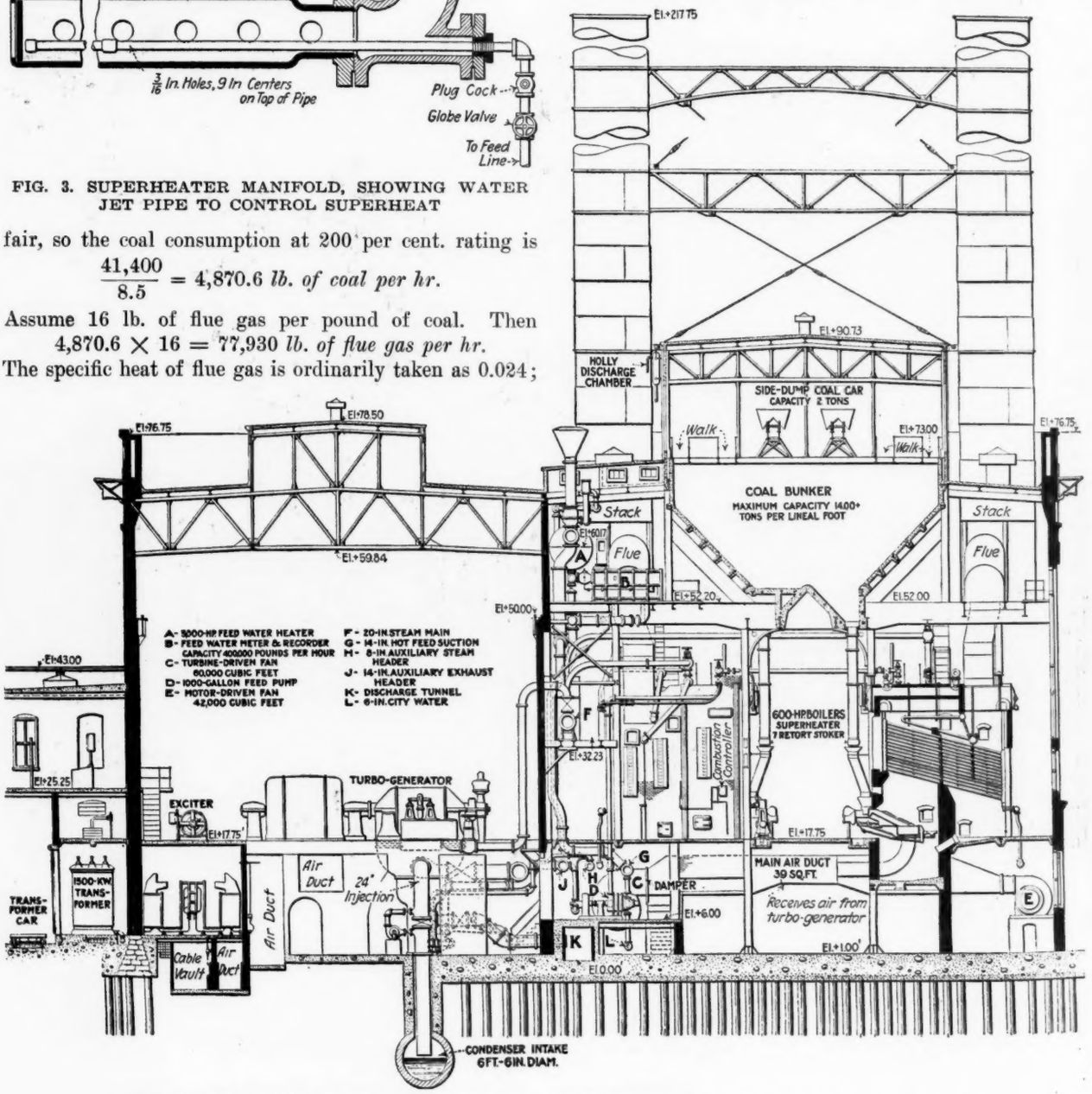


FIG. 4. SECTIONAL ELEVATION, SHOWING ARRANGEMENT OF THE PLANT'S EQUIPMENT

there being 60 deg. drop. The heat absorbed by the drums is,

$$77{,}930 \times 0.24 \times 60 = 1{,}122{,}192 \textit{ B.t.u. per hr.}$$

The heat value (14,600 B.t.u.) divided into this gives the coal equivalent (neglecting losses) gain, or

$$\frac{1{,}122{,}192}{14{,}600} = 76.8 \textit{ lb. coal per hr. per boiler.}$$

Uptakes between boilers and flues are exceptionally short and direct. This feature removes much of the trouble from soot deposits and of course reduces draft losses. The four steel stacks, each 165 ft. high and 10 ft. internal diameter, four boilers to each, are superimposed upon the steel building frame, thus avoiding any obstruction in the boiler room (see Figs. 2 and 4).

Ashes are dumped from the concrete-lined ashpits through gates in the bottom into three-ton motor trucks. Near each pit a hose cock is provided, also a plug socket for a drop light. These features—these "little things," collectively so important—found throughout the station, are of convenience in everyday operation and should be more liberally provided in power stations.

On account of impurities in the available circulating water for condensing purposes, the life of tubes in surface condensers is so short that they are not practical and the jet (Le Blanc) type is used. As the condensed steam from the main units cannot be used for feed water, about 90 per cent. makeup water is required; the other 10 per cent. is obtained from the various auxiliaries. The steam from these auxiliaries is used for feed-water heating in a 5,000-hp. open heater located above the boilers. City pressure forces the water up to the heater, which gives about 45 ft. suction head on the feed pumps. All high-pressure drips are returned to the heater by a Holly system. Low-pressure drips are collected through traps, in a large receiver and elevated to the heater by a low-service pump automatically controlled to avoid flooding.

The 6-in. boiler-feed main forms a loop just above and at the front of the boilers and is supplied by two 6-in. leads from the header just above the feed pumps. Branches are taken off at the alleys between the boilers, one going to the front of the boiler and another to the rear of one of the drums. The latter is an emergency feed in case of trouble with the front branch. From the front branch three 2-in. leads go to the drum heads, and all are controlled from the floor by extended-stem valves. The whole system, including the back feed, is so valved that only a serious emergency would affect more than two boilers; injectors are provided for such cases. The feed water is measured by passing through an 8-in. Crown meter, then to a weir recorder and finally through venturi meters. There are five feed pumps: One 500-gal., one 800-gal. and one 1,000-gal., all turbine-driven centrifugal; and two of the duplex, outside-packed plunger type.

For feed-water heating, exhaust steam from the auxiliaries enters a 14-in. header, from which it passes through two risers to the heater. Back-pressure in this line is limited to 2 lb. per sq.in. by a relief valve. The range between 1½ and 2 lb. is taken care of by a 10-in. heat-balance valve which admits steam at 1½ lb. pressure to the lower stage of the 20,000-kw. turbine, nicely adjusting a heat balance when conditions require. Thermometers in the heater show the average temperature of the feed water to be 210 deg. F., while others on the discharge side of the pumps show a drop of not more than 2 deg. from the heater to the boiler.

Feed piping under 5-in. is of heavy-weight brass; 5-in. and over is extra-heavy cast iron. Steam piping is extra-heavy wrought iron. Boiler nozzles and cross-pipes are of cast steel. Steam valves (high-pressure) have steel bodies, nickel-bronze seats and disks, and monel-

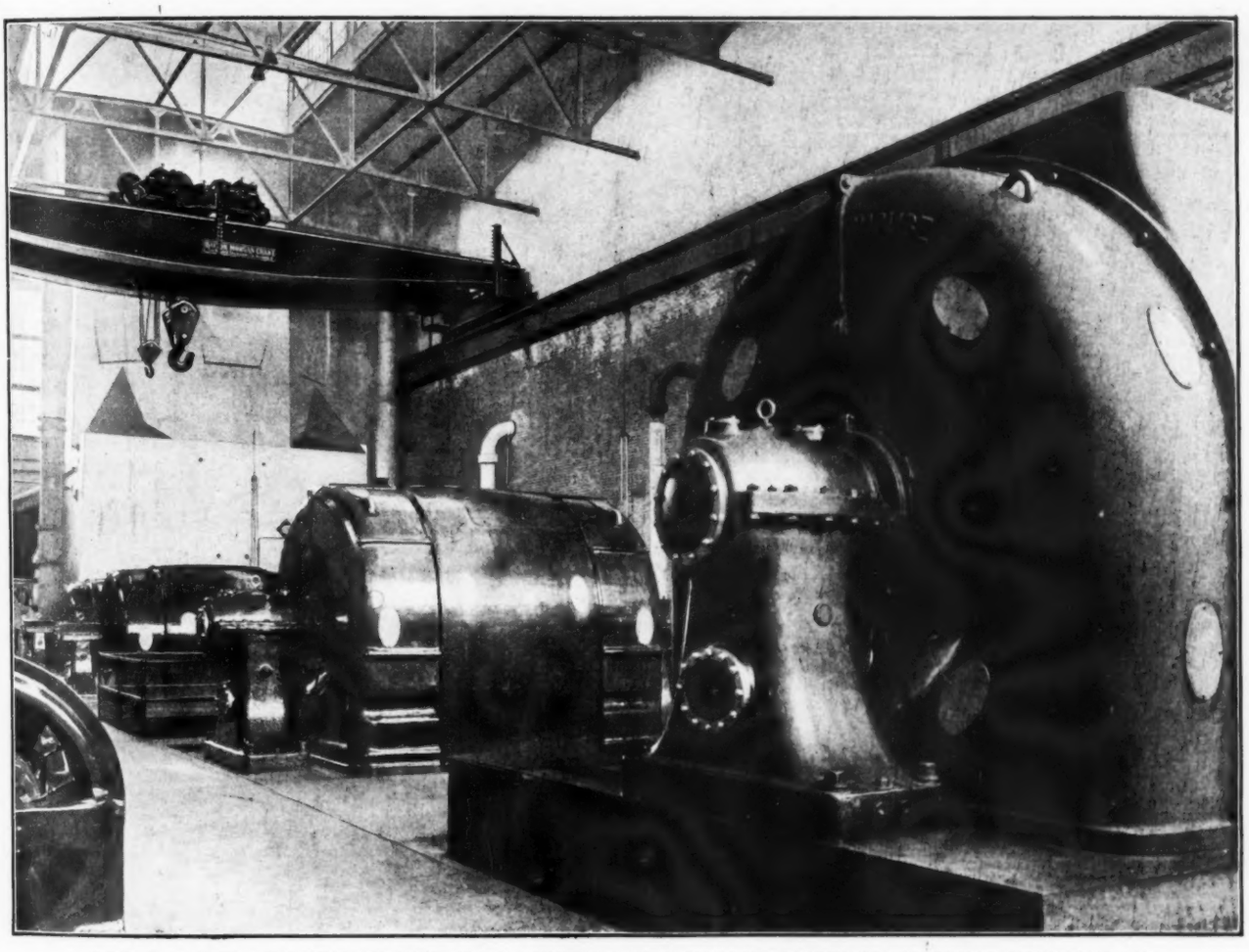


FIG. 5. VIEW OF PART OF THE MAIN TURBINE ROOM, NARRAGANSETT ELECTRIC LIGHTING CO.

metal spindles. No cast-iron fittings were used for steam purposes, and all down to and including 2-in. are flanged. Brass and steel fittings are all extra-heavy. High-pressure piping of all kinds is accepted only after a representative of the Narragansett company has witnessed it tested to 600 lb. All piping 5-in. and over has tongue-and-groove flanges fitted with copper gaskets. The main steam header is 20 in. diameter and is cut into sections so that each has ample boiler capacity for the turbines drawing steam from it, and the section valves may be operated locally or from either the boiler or engine-room floors.

With 2½ to 3-in. air pressure at the furnace the boilers easily develop 200 per cent. rating and show no

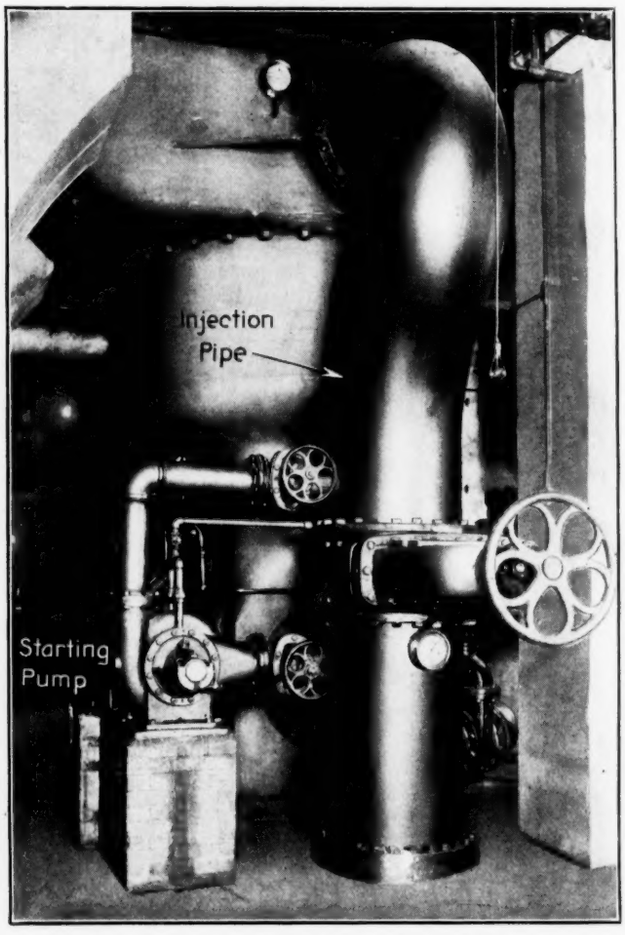


FIG. 6. THE LE BLANC CONDENSER

distress on continuous runs. Coal consumption averages 2.08 lb. per kw.-hr. including all stand-by losses over a considerable period, during which time many different kinds of coal have been tested.

The present turbine equipment consists of one 3,500-kw. single-flow and one each 3,500-kw., 4,000-kw., 8,000-kw. and 20,000-kw. double-flow Westinghouse machines. Fig. 5 is a view of the turbine room.

While muddy and polluted cooling water is unfavorable to surface condensers, no difficulty has been experienced with the low-head jet type, in spite of the fact that they are not protected by foot-valves. The 8,000-kw. condenser at 28-in. vacuum requires 36.2 lb. of cooling water at 70 deg. per pound of steam. The other three are not quite so economical, showing 43 lb., while the condenser of the 20,000-kw. machine is expected to show a big reduction in the quantity of water required. Fig. 6 shows one of the large condensers. The air and water pumps for condensers are all turbine-driven and may be operated either condensing or noncondensing. Three of the

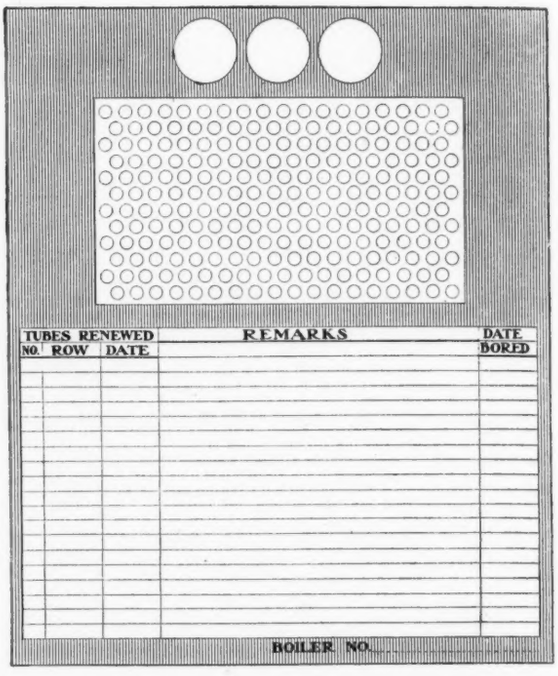


FIG. 7. FACSIMILE OF RECORD SHEET FOR TUBE RENEWALS

generators furnish three-phase 60-cycle current at 2,300 volts, while the other two deliver three-phase 60-cycle current at 11,000 volts.

Of the four exciter sets, two are motor- and two steam-driven. One of the former has a 75-kw. 250-volt generator driven by a 115-hp. induction motor taking current at 2,300 volts. The other has a 60-hp. induction motor driving a 48-kw. 250-volt generator. Of the steam

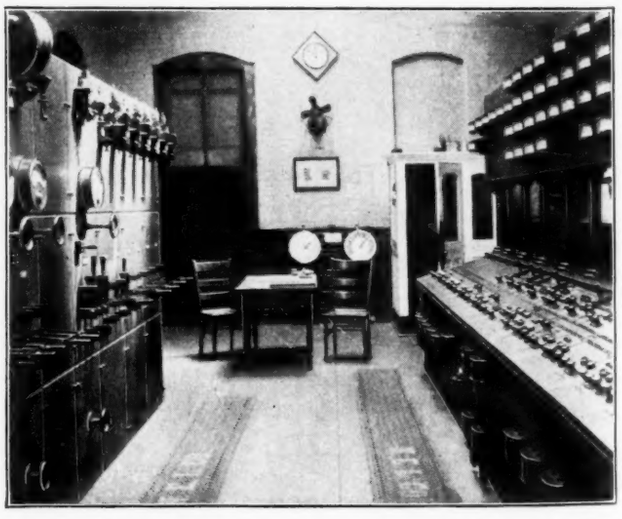


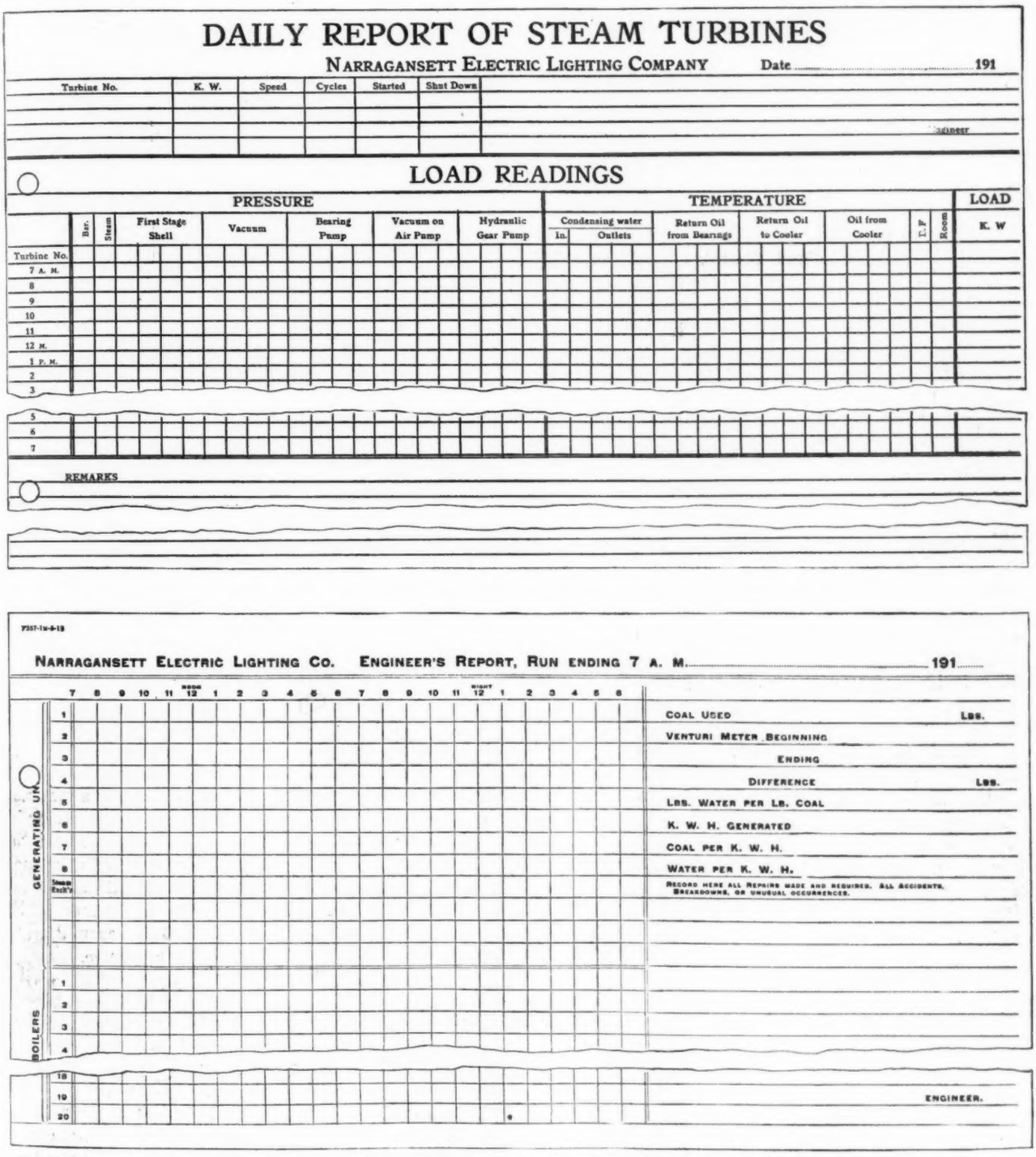
FIG. 8. SHOWING THE MAIN CONTROL BOARD

exciters, one is 100-kw. and the other 200-kw., both driven by noncondensing turbines. The total main-unit capacity plus a continuous overload of 25 per cent. with a total exciter capacity of 423 kw., gives approximately 115 kw. main-unit output to 1 kw. exciter capacity. The exciter bus is double, one set energized from the large

storage battery which floats on the line at a near-by substation; each field has a double-throw switch. The rheostats are in a separate compartment under the main switchboard. The four transformers at the station connecting the 2,300-volt and 11,000-volt busses are oil-insulated and water-cooled. Each occupies a separate compartment.

Six substations distribute energy for lighting and power to practically the whole of Rhode Island. Three of these are in Providence, while the others are within a radius of ten miles of the main generating station.

The Dyer Street station, the main station within the city limits, supplies the 250-550-volt direct-current system within the fire district, it being the only one to receive its 2,200-volt current direct from the central station. Seven motor-generator sets receive this current and deliver 550-volt energy to the station bus, while 11,000-volt taps, brought in from East Providence, supply current to mercury-arc rectifiers operating magnetite-arc circuits. A 1,780-kw. (hourly rating) storage battery also floats on the bus, and a tie between this and the central station supplies excitation current for emergency purposes. From this point 33 feeders supply current to about 1,100 miles of underground cables in the three-wire system, and three feeders supply about 600 miles of 500-volt aërial power mains.


DAILY REPORT OF STEAM TURBINES

NARRAGANSETT ELECTRIC LIGHTING COMPANY Date 191

Turbine No.	K. W.	Speed	Cycles	Started	Shut Down

LOAD READINGS

	PRESSURE							TEMPERATURE						LOAD
	Bar.	Steam	First Stage Shell	Vacuum	Bearing Pump	Vacuum on Air Pump	Hydraulic Gear Pump	Condensing water In.	Condensing water Outlets	Return Oil from Bearings	Return Oil to Cooler	Oil from Cooler	L. P. Room	K. W
Turbine No.														
7 A. M.														
8														
9														
10														
11														
12 M.														
1 P. M.														
2														
3														
5														
6														
7														

REMARKS

NARRAGANSETT ELECTRIC LIGHTING CO. ENGINEER'S REPORT, RUN ENDING 7 A. M. ..... 191 .....

7 8 9 10 11 NOON 12 1 2 3 4 5 6 7 8 9 10 11 MIGHT 12 1 2 3 4 5 6

GENERATING UN.

1 2 3 4 5 6 7 8

Steam Each's

BOILERS

1 2 3 4

18 19 20

COAL USED Lbs.

VENTURI METER BEGINNING

ENDING

DIFFERENCE Lbs.

LBS. WATER PER LB. COAL

K. W. H. GENERATED

COAL PER K. W. H.

WATER PER K. W. H.

RECORD HERE ALL REPAIRS MADE AND REQUIRED. ALL ACCIDENTS, BREAKDOWNS, OR UNUSUAL OCCURRENCES.

ENGINEER.

FIG. 9. TWO OF THE DAILY REPORT SHEETS USED BY THE OPERATING ENGINEERS

The other substations are all 11,000-volt alternating-current installations. Olneyville receives its supply over two cables and delivers current over four 2,200-volt feeders, five magnetite-arc and ten series-incandescent circuits, all underground. Elmwood, through 1,000-kw. three-phase 11,000-33,000-volt transformers, supplies a high-tension transmission line to Narragansett Pier, a distance of 30 miles; also three 2,200-volt feeders, four 75-light mercury-arc rectifiers operating magnetite lamps and nine 35-kw. constant-current tubes operating series-incandescent circuits.

East Providence supplies three 2,200-volt feeders, five series-arc and six series-incandescent circuits. These, up to the distribution points, also the incoming lines, are underground. A single aërial line from this point runs to the Warren station, which in turn supplies the towns of Barrington, Warren and Bristol. This station also supplies an 11,000-volt circuit running to Swansea, Mass., for railway purposes.

The station at Apponaug supplying the towns of Warwick, West Warwick, Coventry, Scituate, East Greenwich and North Kingstown is fed by one 11,000-volt line from Providence and is tied into Warren by a single line, part of which is submarine, crossing Narragansett Bay. Fig. 8 shows the main control board at the South Street station.

Three Ways of Getting Coal to Bunker

The coal-handling equipment is standard and has the largest single tower in the port. The lift of 125 ft. from mean low water is unusual, but the guarantee of hoisting 250 tons of coal per hour was more than fulfilled, as 270.9 tons was transferred from barge to inside the bunker in one hour.

The inside bunker, of steel and concrete, has a capacity of 2,500 short tons, or about twelve days' supply. Outlets in the bottom, 16 in. square, deposit the coal by gravity directly into the stoker hoppers. The bunker is filled from two 2-ton automatic cars, each car being weighed before it is released from the loading platform.

Taking coal directly from the barge is a new departure for this company, and considerable dredging had to be done to allow the largest carriers that come to Providence to get alongside.

The system is flexible, as it provides three methods for getting coal to the bunker. The 2-ton bucket elevates it directly from the barge to the hopper, from which it is crushed and deposited in the cars. The tower is provided with an endless bucket elevator which runs underground so that coal may be carted in teams and pounded through a grillage, then elevated and deposited in the cars as before. The cable railway in the old boiler house runs across the street to the yards of the Eastern Coal Co., from which coal may be brought in and dumped into a hopper that fills the elevator buckets through a chute. Additional storage is contemplated, and necessary changes have been made so that coal may be transferred from the barge or ground directly into the old bunker.

Throughout the station many operating conveniences may be found. A 50-ton crane handles all machinery in the engine room; the latest design signal system for starting and stopping is used; steam-flow meters are connected with each boiler lead; recording thermometers and gages in the pumproom indicate what the heater is doing 45 ft. above the level of the pumproom floor.

Under high rating conditions boiler tubes will bag. At the South Street station the water tender and a helper with the aid of a light examine the tubes after the fires are cleaned and banked. When tubes are replaced a record is entered on the form shown in Fig. 7, the forms have a diagram of the boiler drums and tubes. These records are in card form, easily filed and provide a good means of checking the auditors report on the tubes charged to the plant. Two of the report sheets used are shown in Fig. 9 and are commendable for their simplicity.

The Internal Treatment of Boilers

By George Anderson

The formation of scale is the most common of all boiler trouble. Scale is caused by various substances carried in suspension or in solution in the feed water. Of the substances in solution, calcium bicarbonate (bicarbonate of lime) is precipitated by heating to a temperature of 212 deg. F., calcium sulphate is precipitated to some extent at higher temperatures, while common salt cannot be precipitated, but remains in solution until enough water is evaporated to cause saturation, when the salt crystallizes and then rapidly forms a coating on the boiler surface. When the scale-forming material cannot be precipitated by heating, but solidifies by concentration and crystallization, scale may to some extent be prevented from forming by the frequent blowing-off of the boiler, thus keeping the strength of the brine below the saturation point. This of course applies to marine boilers or boilers using salt water.

Scale-forming material is carried in suspension, in the original muddy cold water or is precipitated in fine particles in the feed-water heater or in the boiler, by heat or by the addition of chemicals. The evaporation of the water in the boiler will cause trouble unless the material thus accumulated is removed. The trouble may appear in the form of soft mud, solid scale or scum. The solid scale varies from a soft chalky, easily removed substance to a hard cement or porcelain substance difficult to remove even with the old sharp chipping hammer. The scum floats on top of the water and may accumulate as a muddy substance, which sinks and forms scale.

The Injurious Effects of Scale

The effect of scale on a steam boiler is to reduce the steam-generating capacity and the efficiency and to impede the transmission of heat through the plate. More often scale causes rupture or bagging of the part of boilers in contact with the flame, resulting in many disastrous explosions and in loss of life. It has been said that $\frac{1}{16}$-in. scale will increase the quantity of coal used 15, and a ¼-in., 60 per cent. Dense hard scale is practically waterproof, is a nonconductor of heat and therefore decreases the steam-generating capacity of a boiler.

The most common method of preventing or removing scale is to introduce sodium compounds into the boiler. Caustic soda, the tannates, carbonates or phosphates of soda are widely used. These change the chemical composition of the scale-forming substances and are kept below a point of concentration by an occasional blowing

down of the boiler. The chemicals mentioned form the base of many boiler compounds. A boiler compound should never be used unless both the ingredients of the compound and the effect it will have on the impurities of the water are known. In the treatment of feed water always start with a careful analysis of the compound. A good compound manufacturer will tell you its composition, and the statement can then be verified by your chemist.

Causes of Scale and Ways of Preventing It

There are many ways of preventing scale-forming matter entering a boiler. When calcium bicarbonate, which is the carbonate held in solution by carbonic-acid gas dissolved in the water, is heated, the carbonic-acid gas is driven off, precipitating an insoluble carbonate. This attaches itself to the plates and compels the frequent cleaning of the heater. Calcium sulphate can be precipitated to some extent by heating to a temperature of 300 deg. F. in a live feed-water heater. Calcium hydrate (milk of lime), sodium carbonate and caustic soda are often used, but are dangerous when used by an inexperienced man.

Incrustation is caused by the deposition of suspended matters, of salts from concentration, and of calcium or magnesium carbonates when the carbonic acid holding them in solution is freed. Calcium sulphate is soluble in cold water but is only slightly soluble at 270 deg. F., and therefore is deposited. Magnesium salts, in decomposing at high temperatures, and the lime and iron soaps formed by saponification of grease also cause scale. As a rule, calcium sulphate causes incrustation; magnesium chloride and acids, corrosion; sodium carbonate, priming; while grease and organic matter result in priming, corrosion and incrustation.

Incrustation may be prevented by filtration, blowing-down of boiler, use of internal collecting apparatus, heating of feed water, chemical or mechanical treatment of water, and by the introduction into the boiler of substances intended to coat the water side of the heating surfaces.

Classes of Scale-Reducing Materials

The substances put into a boiler to lessen the formation of scale may be divided into three classes. In the first class are those attacking the scale-producing material chemically in order to form a substance that may be removed by a cleaning tool. The second class includes substances acting mechanically upon the precipitated crystals of scale-making matter soon after they are formed. These are of a glutinous, starchy or oily nature. They become attached to the surface of newly formed crystals, surrounding them, and when these crystals come together they are robbed of the cement-like action otherwise occurring. In the third class are those acting both mechanically and to dissolve the scale already formed. This "rotting" effect prepares the scale for easy removal.

The ingredients in compounds are soda ash (an impure carbonate of sodium), sodium tannate, caustic soda, salsoda, acetic acid and other less efficient agents of which clay, chalk, sand and such coloring matters as tobacco juice, iron scraps, lampblack and spent tanbark are examples.

Although there are other precipitates, notice of the principal scale-making impurities in boilers, the carbonates and sulphates of calcium and of magnesium, will be sufficient for present consideration. Sodium carbonate acts upon the sulphates of calcium and magnesium to form carbonates of calcium and magnesium respectively. Sodium sulphate is formed in both instances. The carbonates of calcium and magnesium are held in solution as bicarbonates when carbonic-acid gas is dissolved in the water. When water containing the bicarbonates is heated the carbonic-acid gas is driven off, leaving behind the practically insoluble carbonates, which are precipitated. A considerable percentage of the carbonates thus formed is precipitated at 180 deg. F. At 290 deg. F. (or 43 lb. gage pressure) the precipitation is, after a thorough boiling, nearly completed.

Characteristics of Compounds Formed

Scale formed from calcium carbonate is seldom troublesome unless allowed to accumulate in too large a quantity or to remain too long in the boiler. The precipitated magnesium, which is seldom in scale as a carbonate, gives slightly more trouble, but all the contained carbonic acid is usually lost from the bicarbonate before a crust is formed. The hydrate of magnesium is left behind and cements and binds closely together whatever precipitated matter it may touch. Hydrate of magnesium is very fine and light when precipitated and requires a comparatively long time to settle.

The sulphates of calcium and magnesium are very soluble, dissolving in water without requiring the presence of carbonic acid or any other foreign agent. The calcium-sulphate crystals are long and needle like and have very heavy cement-like qualities. They fall rapidly and, mixing with the precipitated carbonates, bind them into a hard mass which is difficult to remove even with a hammer and chisel. The precipitated carbonates of calcium and magnesium form a scale varying from a more or less porous, pliable crust to a mush or mud. The sodium sulphate formed by this reaction is extremely soluble, remaining in solution at nearly all temperatures and forming no scale unless allowed to concentrate. Even this is prevented by the blowing down of the boiler frequently.

The tannin is obtained from sumach, gallnuts, catechu bark and similar vegetable sources containing tannic acid. Tannin combined with soda forms sodium tannate, which is used with boiler waters to keep the deposits soft or in suspension. The sodium tannate decomposes the carbonates of calcium and magnesium as they enter the boiler. Tannates of calcium and magnesium are precipitated in a light, shapeless form and are long kept in suspension by the circulating water, until they finally are deposited in a loose mushy mass in the mud drum or other parts of the boiler where the circulation is weakest. Sodium carbonate is then formed and reacts with any sulphates present, as has been described.

Some Undesirable Compounds

Tannic acid cannot be recommended, as it will attack the iron as well as the carbonates. To demonstrate this, dissolve the crystals of tannic acid in a glass of water, and add some iron filings. The action of tannic acid on the iron results in a fairly good quality of ink.

An excess of either the carbonate or the caustic soda causes foaming in the boiler, and the impurities will be carried along the steam lines into valve seats, gage-

glasses, and steam gages. Caustic soda attacks the brass fittings and is also dangerous to handle, burning the flesh or anything with which it may come in contact. Sal-ammoniac is most undesirable for use in a boiler, owing to the liberation of hydrochloric acid. This acid in a vaporous form passes along with the steam, corroding the boiler, piping and everything it touches. Other compounds contain some bisodium or trisodium phosphates. The latter is the denser, and reacts with calcium sulphate. The calcium phosphate falls, forming a slushy mud or a weak crust, while the sodium sulphate remains in solution, as previously explained. Fluoride of sodium is another compound that seldom does any good. The fluoride of calcium precipitated in a boiler behaves much like the calcium phosphate.

A class of compounds now falling into disuse contains slippery elm, ground bones, horns and hoofs, potatoes, dextrin, starch and animal and vegetable oils. These make the water thick and oily and coat the boiler with a thick nonheat-conducting scale, causing bags and laminations in the plates. The scale crystals precipitated from the feed water fall into this fluid and become coated with its filth, until the mush thus deposited burns out and forms a loose scale. When any of these compounds are used the boiler should be blown down frequently.

Where a hard scale has formed, flake graphite in combination with kerosene is used beneficially. The shell is first given a coat of kerosene, which rots and cracks the scale. Graphite will then work its way behind the scale and with the expansion and contraction of the boiler the scale falls from the shell in large quantities. When given this treatment boilers should be opened frequently to prevent the burning of the shell by large quantities of scale settling at the bottom.

Out of over 1700 boiler inspections made by the writer, 740 boilers were rendered dangerous by deposits of sediment, 820 by incrustations and 150 by general internal corrosion. These figures show that a preventive is often required. The life of a boiler depends on its internal condition. A boiler kept clean internally can be safely given 40 years of life, but with scale and corrosion the life is much less. Too often at a time when least expected a new boiler must be bought. It will be realized then too late that the old boiler would have lasted for years longer had a little good work been done in keeping the interior clean.

High-Pressure Steam for Superheating

By R. L. Shipman

SYNOPSIS—It is proposed to use a small independent boiler to supply steam at 500 lb. pressure or higher to superheat steam at 100 lb. pressure in a closed heater located near the engine throttle.

It has been conceded by eminent engineers that the use of superheated steam is one of the greatest sources from which economy may be expected in the steam engine. The principal efforts in this direction have been made along the lines of boiler improvements to get the heat from the more or less cooled gases of combustion, especially just before entering the flue. In a well-designed and well-operated boiler the temperature of the flue gases is little higher than that of saturated steam at the boiler pressure, being hardly sufficient to create the necessary draft. Superheaters so arranged are usually some distance from the engine, and the loss by radiation from the large steam line is probably more than most engineers realize. In my own experience with one of the latest improved superheating boilers, in which a temperature of steam at the boiler of 500 to 700 deg. was commonly obtained when working it up to its rated capacity of 100 hp., it was found that with an engine using about 60 per cent. of the boiler capacity through a 3-in. steam line about 100 ft. long with double asbestos lagging, the difference in temperature of the steam between the engine and the boiler was usually more than 100 deg. The radiation loss from the steam main alone amounts to a considerable percentage of the total heat put into the steam, and the temperature of the steam is a fleeting thing, going anywhere within a range of 200 deg. within short periods, depending upon how the fire is worked and the amount of steam required.

Cylinder condensation is the source of one of the greatest losses of efficiency of the steam engine; and while, theoretically, it would require some 300 to 400 deg. of superheat to annul this, it has been repeatedly proven by experiment that 100 to 150 deg. practically annuls all cylinder condensation, the first 50 deg. or so being the most valuable; and it has further been found that 100 to 150 deg. of superheat is quite necessary and ample in steam-turbine practice.

By consulting the steam tables it may be seen that the temperature of steam at 500 lb. gage is about 133 deg. above the temperature of steam at 100 lb. gage and should easily superheat that steam 100 deg. in a properly designed superheating receiver. The latent heat of steam at 500 lb. gage is about 758 B.t.u. The mean specific heat of saturated steam at 100 lb. gage and steam at the same pressure superheated 100 deg. is 0.54. Then since it takes 0.54 B.t.u. to superheat one pound of steam one degree, 758 B.t.u. would superheat 14 lb. of steam through 100 deg., and the heating surface in the high-pressure boiler would need to be only about 7 to 8 per cent. of that in the low-pressure boiler.

Now the high-temperature steam is wanted at the entrance to the engine or turbine. Then if a well-insulated receiver is placed near the steam chest and is supplied with high-pressure steam-heating surface over which the low-pressure steam must pass on its way to the engine, the high temperature is obtained where it is wanted. This high-pressure steam could be furnished by a special high-pressure boiler located in the room with the other boilers and fired by the regular fireman. Special precautions could be taken to make every joint tight in the high-pressure boiler, as it would seldom, if ever, be necessary to clean it, the same water being used over and over again

and in most cases returned by gravity. Where it could not be returned by gravity the difference in pressure necessary to pump against would be very slight. With this method of superheating the temperatures would be under perfect control. There would be no danger of burning out the superheater, nor of the steam attaining a temperature dangerous to the metal or lubricant of the engine. The high-pressure boiler could be of cheap tubular construction, as very little means for cleaning need be provided, and it would not be necessary to provide a spare one. It also seems probable that the water in this boiler could be treated chemically so as to avoid corrosion, thereby making the charge for depreciation and repairs light. It has been proven that with superheated steam, steam jacketing, which always means expensive steam-engine construction, is unnecessary. It is doubtful if a plant arranged as herein suggested, with nonjacketed engines, would be as expensive in first cost as one arranged in the usual way with jacketed engines, and the saving by superheating would far exceed that by jacketing.

The question of durability of heating surface in the high-pressure boiler and the superheating receiver is not a serious one, as data are available from boilers working at from 800 to 1,000 lb. pressure, and there is a great deal of information on the use of reheating receivers in connection with multiple-cylinder engines. Past experience with reheating receivers will forestall any question as to abnormal heating surface being required in them. The rate of flow of heat through the walls from high-pressure steam on one side to low-pressure on the other and the arrangement of the heating surface for best results are the most important problems that present themselves for practical solution. From data at hand it seems that the rate of flow of heat through the steam-heating surface will increase as the pressure increases. This would naturally be expected, owing to the increasing density of the heating medium.

Throttling High-Pressure Steam

It has been suggested that if this small amount of high-pressure steam be throttled into the steam chest of the engine, thereby mixing the low-pressure steam, the same degree of superheat would be obtained as by condensing it at high pressure. A brief consideration of the principles involved will show that this is not possible. Remembering that the total heat of steam is the same on both sides of a throttle and using an entropy chart, it will be found that throttling from 500 lb. gage pressure down to 100 lb. gage pressure will give only about 40 deg. of superheat when the steam is perfectly dry on the high-pressure side of the throttle. Then this small amount of superheated steam would not go far toward superheating fourteen times its weight by the method of mixture, and if the high- or low-pressure steam contained any moisture the result would not be so good, depending upon the amount of moisture contained. Besides, the work of pumping the water into the high-pressure boiler would be no small consideration.

Many engineers claim that they can find no saving by using their reheating receivers. But this should not be construed to discredit this method of superheating, because these are cases where the reheating receivers are flooded with water and all of the heat goes to evaporate water and none is left to superheat the steam after the moisture is evaporated. The evaporation of this moisture at a low pressure by high-pressure steam always means a loss and should be avoided. A quantity of heat put into steam in the form of superheat, up to a certain degree, is worth many times that amount of heat used in generating saturated steam at the same pressure, and that is why it is economical to sacrifice steam at a high pressure to superheat steam at a lower pressure. In any case it is important to separate the moisture from the working steam before going into a superheating receiver, and after this heat has been put into the steam as superheat use precaution to protect it against radiation.

From the best authorities upon the subject it would seem that a saving of 10 per cent. in the fuel consumption of an ordinary steam-power unit might be expected by the use of steam superheated around 100 deg., or less, just enough being supplied so that no superheat will appear in the exhaust. Then take, for example, a 100-hp. plant using 3 lb. of coal per horsepower-hour, or 1,080 tons per year of 300 days of service. A 10-per cent. saving of this would be 108 tons, which, at $3 per ton, would amount to $324 per year. This is 10 per cent. of $3,240, an amount about four times greater than the probable cost of the superheater.

Size and Design of Superheating Unit

If, with superheating, the 100-hp. set used 90 per cent. of the coal used without superheating and 10 per cent. of this amount were used in the superheater, it would have to burn 97 tons a year, or less than 2 tons a week. From experience with boilers for heating residences it is known that a boiler burning only a ton or two a week would not occupy much space in spite of the fact that these boilers are usually made of cast iron and occupy a comparatively large space for the amount of heating surface they contain. Then a boiler of proper tubular construction to burn this amount of coal would occupy so little space as to admit in many cases of being placed in the engine room near the engine or turbine to which it is to supply heat. The superheating receiver would be placed in the steam main just above the engine, and the condensation from this receiver would flow back by gravity into the high-pressure boiler. With this arrangement it would not be necessary to place valves in the lines between the high-pressure boiler and the superheating receiver. The feed water, which should be almost negligible in amount, should be distilled water and could be fed by means of a hand pump. The small amount of coal required by the boiler could be fed from a magazine, watched and replenished by the regular engine attendant, and the ashes could be disposed of by means of a steam siphon to avoid dirt in the engine room. Draft regulation should be effected by an automatic damper.

It is important to note that the superheater is especially adaptable to the lower-grade plants, thereby affording the economy of compounding and often where otherwise compounding would be out of the question. This superheating installation would probably cost less than to place a cylinder in tandem on an existing engine for the purpose of compounding, and it would appear that the superheating set might effect a greater saving than the compounding.

For a superheating set that can meet the conditions, the field of application is practically unlimited, and it is hoped that the facts and figures herein presented will induce manufacturers to try out some designs.

Foreign Gases and Solids in the Absorption Plant*

By H. G. Gibson

SYNOPSIS—The gases are air and gases from decomposed ammonia; they show their presence by causing an increase in the generator, absorber and cooler pressures. Iron oxide in the generator sometimes covers some of the heating surface. The author believes that it is reasonable to suppose that decomposition of ammonia increases as its temperature increases.

Permanent gas, which includes atmospheric air and gases generated from impure and decomposed ammonia, is one of the principal causes of inefficient and erratic-working absorption refrigerating systems. Atmospheric air is not likely to give as much trouble as gas, because there are few opportunities for air to get in except when the machine is being started after an extended shutdown. After such a shutdown, especially if the apparatus has been opened for repairs, efforts to clear the machine of air should not abate until all the air is exhausted, for a small amount circulating or pocketed in the system will decrease the efficiency considerably.

Air Gets in Through Stuffing Boxes

The piston-rod stuffing-box of the ammonia pump affords the most likely inlet for air while the machine is running. For this reason the packing around the rod and the rod itself should be kept in good condition. With a vacuum in the absorber and the rod or packing defective, there is nothing to prevent air being sucked into the pump and forced into the generator.

The presence of permanent gas in the machine manifests itself in various ways. One of the surest signs is an increase in generator, cooler and absorber pressures, other factors remaining the same. Another indication is the seeming inability of the generator to produce anhydrous in the condenser with a reasonable amount of steam pressure. Regardless of the source of the gas, it will eventually find its way to the condenser and absorber; if the gage-glasses on these shells are open and there is any liquor in sight, unmistakable evidence of the presence of the unwelcome gas will manifest itself in these glasses. In fact, it will be useless to try to determine the actual height of liquor in these shells until the "offending" pressure is released or is forced into some other part of the machine.

The absorber is the proper place from which to draw the foreign gas. Two outlets are provided on the absorber for this purpose, one near the top and one near the bottom of the shell. The bottom outlet is handier and under ordinary circumstances will afford adequate means of relief. Both outlets should be fitted with a rubber hose or, better still, a swinging pipe that can easily be adjusted to discharge into a bucket of water.

When using the bottom outlet the level of the liquor in the absorber should be brought down below the gas-discharge p.pe outlet. With the end of the hose or swinging pipe placed in the water, the nature of the discharge can be determined by its action as soon as the stop valve is slightly opened. If air or other permanent gas is coming out, bubbles will rise from the end of the pipe to the surface of the water. If the discharge will ignite, the presence of gas generated from impure or decomposed ammonia is apparent; if not, air is the principal source of pressure. If ammonia gas is the principal component of the discharge, the water will not bubble appreciably and will soon indicate the presence of ammonia by the smell. The discharge valve should be left shut when the presence of ammonia is indicated.

A quicker, though not so handy, way of purging the apparatus of foreign gas is to use the outlet near the top of the absorber shell. Then it will be necessary to temporarily stop the ammonia pump and open wider the weak-liquor valves between the generator and absorber. The gas valve between the absorber and cooler should be shut; this will obviate any necessity to purge the cooler before again starting the machine. With these arrangements the weak liquor will rapidly fill the absorber and in so doing will force the objectionable gas to the top under pressure. From here it may be allowed to escape through the upper outlet. This operation may have to be repeated more than once before the gases are all out.

Iron Oxide in the Generator

Iron oxide as a detrimental factor in absorption-plant operation is probably not so well known. Its principal lodging place is in the bottom of the generator, where it settles and slowly fills up the spaces between the steam coils. Unless the generator is opened, the presence of the oxide will not manifest itself except by decreasing the efficiency of the machine, and this will transpire so gradually that the true cause of the trouble will not be suspected.

I know of one instance where a plant had been in operation for several years without an overhauling. Something happened that made it necessary to open the generator, and when this was done considerable iron oxide was found to have accumulated in the coil spaces. Investigation brought out that the corrosion and consequent oxide were caused by the introduction of aqua ammonia in which there was present acetic-acid salts. Acetic acid is an organic compound; in fact, the most common organic acid. When present in the generator it first takes the iron in solution and then gives it up as an oxide. Without detailing the chemical changes involved, it may be said that the interaction of the acid and the iron forms a compound resembling soot, which falls to the bottom of the generator and gradually fills up the spaces between the steam coils.

It is important that the heat-radiating capacity of the coils be maintained at the maximum, for it is reasonable to suppose that the rate of decomposition of ammonia increases as the temperature increases. If the

*Another article on foreign and explosive gases in the refrigeration system was printed Nov. 23, 1915, page 715.

iron surfaces in the generator oxidize because of the presence of acetic acid in the ammonia, the oxide will fall to the bottom of the generator, cutting off a certain amount of radiating surface. To get the normal amount of work out of the machine, more steam will have to be turned on. This means higher temperature and a consequent greater rate of decomposition. To avoid the possibility of experiencing this trouble, only ammonia free from acetic acid should be used, and a guarantee to that effect should be obtained from the manufacturer, who probably could remove the acid from the product without much difficulty if he was given to understand the necessity for so doing.

Pipe-Fitting Suggestions

By W. D. Forbes

The object of this article is to call attention to certain facts in connection with fittings and pipings which are often overlooked or not thoroughly considered, and to suggest substituting for the present fittings, connections made possible by the numerous portable welding apparatus now obtainable.

The primary function of a line of piping is to convey steam to various machines with the fewest possibilities of leakage; that is, the fewest joints, with the least weight and at the least first cost for material and the lowest possible cost for erection, not neglecting the matter of radiating surface. The manufacture of pipe fittings has been brought to a very high state of perfection in the United States, and there are obtainable today in all our large cities and in many of our small ones, fittings of admirable design and workmanship, in cast iron, composition and steel castings in infinite variety.

These fittings are made in two styles—with flanged and with screwed ends. No doubt there are misgivings in the minds of many engineers as to the reliability of a screw joint. This is possibly due to the recollection of the old system of straight threads, locknuts and grommets. But there is no reason for this when the taper thread, now universal, is used; as we find boilers on the market in which screwed joints are used directly in the firebox. After a long acquaintance with this type of construction, the writer has never seen a leaky joint, and certainly no more severe test could be found.

Comparison of Flange and Screw Fitting

Compared with the flange fitting, which is so popular, let us select a 4-in. tee for a concrete example. Here we have a body, 3 flanges, 3 gaskets, 24 bolts and nuts—a total of 55 pieces. The opportunities for a leak are six—three where the screwed joints are made in the flanges and three where the flanges join.

The weight of this fitting with its flanges and bolts is 52 lb. To erect or put in place this tee and make up screwed or expanded joints in the flanges will usually take 40 min. for two men; that is, if the position is not too cramped to be conveniently worked in. The radiating surface is also much greater than that of the screwed-joint fitting, and its cost is much more than that of the screwed-end fitting. We have, therefore, as the disadvantages of this type of fitting, maximum possibility of leaks, maximum cost, maximum weight and maximum of time to put in position.

As to its advantages, the majority of those questioned as to why they preferred the flanged fitting, answered, "because it is so easy to take down;" others said they prefer it because "it is so much easier to tighten up the flange if it leaks;" while a few asserted, "it looks better." A very few consider it more permanent and stronger. Certainly "looks" is a matter of taste and not a question of engineering. As to strength, there is no doubt that if not properly supported, a run of pipe with flanged fittings would be stronger than one made up with screwed fittings, but there is no excuse for not properly supporting pipes.

The assertion that the flanged tee is more easily taken down is true, but it is hardly conceivable that thoughtful people will erect piping disadvantageously merely that it may be more advantageously removed. In the screwed-end tee we have a single piece with three possibilities of leakage, only half the number in the flanged tee. Its weight is 18 lb., and it usually takes two men under fair circumstances about 20 minutes to make it up. It will also be noticed that the radiating surface of the screw-end tee is much less. To recapitulate, the disadvantages of the screwed-end fitting are that it is not as easily removed, nor is it as strong. Its advantages are less weight, fewer possibilities of leakage, less radiating surface, less first cost and less cost to put in position.

Choice of Fittings to Be Used

An equilateral tee can, of course, be properly used only when the steam which passes through it is diverted by one of the outlets being completely shut off. That is, steam is led through the run to a machine while the side outlet is cut off, or the steam is led through the side outlet to a machine with the run cut off. It is evident that if the outlet and run are to convey steam to two machines at the same time, their combined area must not be greater than that of the inlet. This, if properly designed, would result in what is known as a reducing, or bull-head, tee, but as such fittings while obtainable at the factory are not often carried in stock, the regular tee is bought and the outlets are either bushed or flanged for smaller pipe. This results in extra weight, but is commercial and more convenient.

The primary object of the tee fitting, of course, is to lead steam to various machines. It is evident that it is advantageous to keep the steam flow as direct as possible, that is, to prevent abrupt turns. The ordinary tee requires a right-angled turn, which is admittedly bad. There is a fitting readily obtainable on the market, infinitely better suited to perform the function of a tee, yet it is rarely used. This is the lateral, usually called a Y. Here the steam on the run takes the same direction as in the regular tee, but in the side outlet it is led at an angle of 45 deg., which is far more advantageous than the right-angled turn. When this fitting is used in connection with a quarter-bend pipe, its appearance is very pleasing. Its cost is about the same as the regular tee, and it fills the requirement of conducting the steam far better.

In late years the introduction of welding apparatus that is convenient and portable places in the hands of engineers means of making pipe connections at less cost, of less weight, and more free from the possibility of leakage than either screwed or flanged fittings. This

method of joining pipes has proved satisfactory for water connections on board ship, and the operation is simply a time-honored one of bossing a steel steam pipe, as has been done with copper piping for so long a time.

Instead of using a tee connection either flanged or screwed, why not a steel boss, properly rounded to fit the curve of the pipe, welded in position and then drilled and tapped for the side outlet? Here we would have the minimum cost and possibility of leakage—only one.

Those using the welding process constantly maintain that a boss of proper size to be tapped for ½-in. pipe can be readily welded at a cost for labor and gas not exceeding ten cents, and the cost of such a boss, punched out and formed in quantities, would not be over eight cents. Added to this cost would be that of drilling and tapping, which would probably be twelve cents and its weight would be ½ lb. There seems to be nothing to note against the use of such a connection. It has in its favor lightness, minimum possibility of leakage, cheapness and small radiating surface.

A properly formed boss could be readily made so that the side outlet could come out at any desired angle instead of a right angle, but it would cost somewhat more than a plain piece. There is one difficulty in its use—in drilling and tapping the boss it would be impossible to prevent some of the chips remaining in the pipe, and while these could be easily removed from unassembled piping, it would be difficult in work already in place; but, with the advantages enumerated, this difficulty would seem to be overbalanced.

Spark Gap Under Different Ignition Pressures

By L. A. Quayle

It seems that comparatively few gas-engine operators or automobile drivers know that there is a material difference between the distance a spark will jump under atmospheric pressures and under compression pressures of four to seven atmospheres, which obtain in gasoline- or gas-engine cylinders. The relation between the compression pressure and the maximum distance sparks from a magneto or spark coil will jump in a continuous unbroken stream when the magneto, or spark coil and battery, or generator is in good condition, is shown in Fig. 1. The average length of the sparks is also shown. The data for this curve were obtained in the following manner:

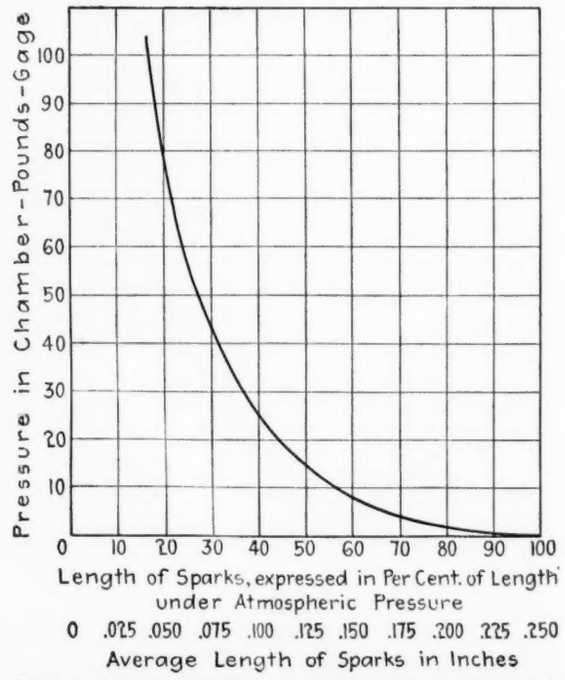


FIG. 1. CURVE SHOWING VARIATION OF SPARK WITH PRESSURE

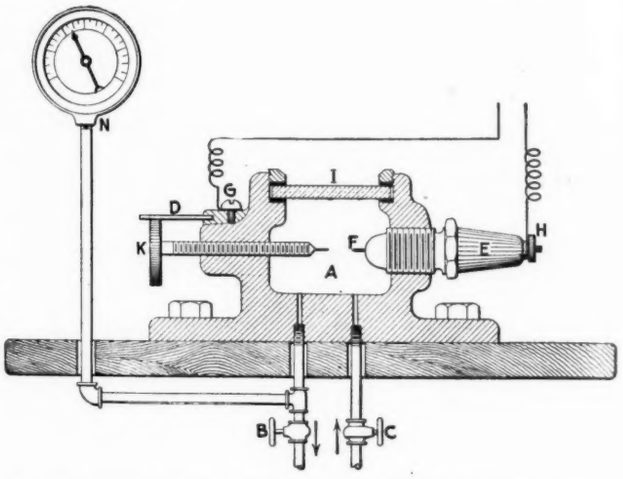


FIG. 2. APPARATUS USED IN EXPERIMENTS FOR DETERMINING VARIATION OF SPARK GAP

The malleable-iron pressure chamber shown in Fig. 2 was connected by a ¼-in. pipe to a receiver which contained air at 100 lb. Any desired pressure from atmospheric to 100 lb. could be maintained in the chamber by adjusting valves *B* and *C* and watching pressure gage *N*. Into the pressure chamber a special spark plug *E* having an insulated point *F* was screwed. Directly opposite this plug was a screw with the notched wheel *K* and pointer *D*. Shifting one notch on the wheel changed the distance between the stationary and the movable points 0.005 in. The pressure chamber *A* was provided with a sight glass *I*, made air-tight by two rubber gaskets. The high-tension wires from the coil or magneto to be tested were connected at *H* and *G*.

To determine the maximum distance sparks under a given pressure would jump, the movable point was screwed against the stationary point to check the zero reading on notched wheel. The air in the chamber was then regulated to the desired pressure, the primary circuit closed and the movable point gradually screwed back from the stationary point. The distance between the points and the pressure in the chamber were recorded just before the sparking became slightly irregular. The spark points could be separated considerably further before the sparks would cease to jump at irregular intervals.

The curve as plotted is the average of readings taken on several types and makes of spark coils and magnetos, and while there is a considerable variation in the length of the sparks given by the various types of apparatus, they all closely follow the general characteristic of the curve.

In view of the foregoing, it is well when conditions allow, to disconnect the high-tension wires from the spark plugs and determine whether or not the ignition apparatus will give sparks from ⅜ to ¼ in. in length under atmospheric pressure.

Fundamental Principles of Alternating Current--III

By F. A. Annett

SYNOPSIS—Relation between frequency, number of poles and speed of a synchronous machine. The effective value of an alternating current.

It was shown in a preceding article of the series that each time a conductor or group of conductors passes a pole an alternation is generated; therefore the number of alternations per revolution equals the number of poles. Since one cycle equals two alternations, it follows that the cycles per revolution $= \frac{\text{alternations per revolution}}{2} = \frac{\text{number of poles}}{2} = \frac{p}{2}$, where p is the number of poles. If S represents the speed of the armature in revolutions per minute, then the revolutions per second will be $\frac{S}{60}$. The cycles per second, or frequency, f equals the cycles per revolution $\left(\frac{p}{2}\right)$ multiplied by the revolutions per second $\left(\frac{S}{60}\right)$, or

$$f = \frac{p}{2} \times \frac{S}{60} = \frac{pS}{120} \qquad (1)$$

This is the formula for finding the frequency of an alternator and may be resolved into two others—one for finding the number of poles where the frequency and the speed are known, which is $p = \frac{120 \times f}{S}$; and another for finding the revolutions per minute where the number of poles and the frequency are known, that is, $S = \frac{120\,f}{p}$.

Since the alternations per revolution equal the number of poles, it follows that the alternations per minute will equal the number of poles times the revolutions per minute, or pS. Substituting in formula (1), $f = \frac{\text{alternations per minute}}{120}$, whence alternations per minute $= 120\,f$.

The following examples illustrate the use of the preceding formulas:

1. Find the frequency and alternations per minute of a 20-pole alternator running at 150 r.p.m.

The frequency, $f = \frac{pS}{120} = \frac{20 \times 150}{120} = 25$ cycles per second. The alternations per minute $= pS = 20 \times 150 = 3{,}000$.

2. Find the number of poles in a synchronous motor running at 1,200 r.p.m. on a 60-cycle circuit.

$$\frac{120\,f}{S} = \frac{120 \times 60}{1{,}200} = 6 \textit{ poles}$$

3. Find the speed of an 8-pole induction motor connected to a 7,200 alternation per minute circuit.

$$= \frac{\textit{alternations per minute}}{120} = \frac{7{,}200}{120} = 60 \textit{ cycles}$$

and

$$S = \frac{120\,f}{p} = \frac{120 \times 60}{8} = 900 \textit{ r.p.m.}$$

The last formula gives the theoretical, or synchronous, speed of an induction motor; the actual speed is less, the amount depending upon the slip.

There can be little question as to just what a voltmeter or ammeter should indicate when connected to a direct-current circuit, for the voltage is approximately constant and the current varies only as the resistance of the circuit. In an alternating-current circuit, however, this is not so clearly defined, for here the e.m.f. and the current are not only constantly changing in value, but also in direction. At first thought probably the most logical answer would be that the instruments will read the average value of the curve. This average value could be found by taking a large number of instantaneous values of the curve, adding them together and dividing the sum by the number of values taken. Or, it can be shown mathematically that the average ordinate of a sine curve equals 0.636 times the maximum value.

This value might be indicated on the voltmeter or ammeter were it not for the fact that the effective value of an electric current in a circuit varies as the square of the current times the resistance. This effective value of an electric current is its heating value, and an alternating current is said to be equivalent to a direct current when it produces the same amount of heat. Since this heating effect at any instant does not vary as the current but as the square of the current, it follows that to get the heating effect of the current in an alternating-current circuit at any instant, it will be necessary to square the instantaneous value. Then the average heating effect will equal the average of the square of all the instantaneous values, and the square root of this will give a value equivalent to the direct current amperes necessary to produce the same amount of heat. Thus, to find the effective value of an alternating current take the square root of the average of the squares of all the instantaneous values. This effective value is often called the square root of mean squares and is equivalent to 0.707 times the maximum value.

As has been stated, the ammeter will read the effective and not the average value of the current. The question may arise as to why the voltmeter reading on an alternating-current circuit will follow the same law. This will be readily understood when it is remembered that as far as the indicating device is concerned, it is alike in both instruments; the difference is in the way they are connected in the circuit. A good illustration of this is found in the type of combination voltmeter and ammeter shown in Figs. 24 and 25, the former representing the connections for reading amperes. Assume the resistance of the ammeter coil to be 10 ohms and that of the shunt 0.01 ohm. This gives two circuits in parallel, one of 10 ohms and one of 0.01 ohm resistance, and according to the law of parallel circuits the current will divide in inverse proportion to the resistance of the two circuits; that is, for every ampere that flows through the shunt

there will be 0.001 amp. flowing through the instrument coil. As indicated in the figure, when 100 amp. is flowing through the shunt 0.001 of this, or 0.1 amp., will flow through the instrument, making a total of 100.1 amp. in the external circuit, and if properly constructed and calibrated the instrument will indicate 100 amp. approximately.

If the same instrument is connected across a 100-volt circuit, as in Fig. 25, and the switch S is pressed down, the resistance of the path through the instrument will be $990 + 10 = 1{,}000$ ohms, and the current is $I = \frac{E}{R} = \frac{1{,}000}{100} = 0.1$ amp., which is the same as when the instrument was connected as an ammeter; consequently it will indicate the same. Instead of indicating 100 amp., it will now indicate 100 volts. Therefore it is obvious that the movable element of a voltmeter is subject to the same law as that of an ammeter and if the ammeter reads mean root squares, as previously explained the voltmeter will also read the same.

The foregoing may be summarized as follows: *The average of an alternating current or voltage sine curve*

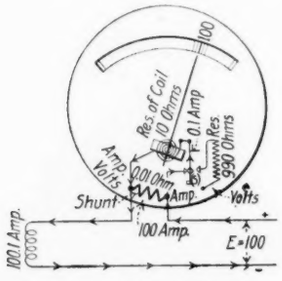


FIG. 24. INSTRUMENT READING AMPERES

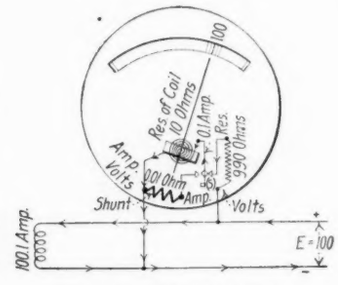


FIG. 25. INSTRUMENT READING VOLTS

equals the maximum value × 0.636. The average value is of very little importance, as it is not what the instruments read and is therefore seldom used. The effective value of an alternating current or voltage sine curve is the maximum value × 0.707, or the maximum voltage, $= \frac{\textit{the voltmeter reading}}{0.707}$, *and the maximum current* $= \frac{\textit{the ammeter reading}}{0.707}$.

The following examples will illustrate the use of these formulas:

1. In a given alternating-current circuit the voltmeter reading is 230, the ammeter reading 75. Find the maximum value of the e.m.f. wave and the maximum value of the current wave.

$$\textit{Maximum e.m.f.} = \frac{\textit{voltmeter reading}}{0.707} = \frac{230}{0.707} = 325 \textit{ volts}$$

$$\textit{Maximum current} = \frac{\textit{ammeter reading}}{0.707} = \frac{75}{0.707} = 106 \textit{ amp.}$$

2. Find the ammeter reading and the voltmeter reading of an alternating-current circuit, where the maximum current is 60 amp. and the maximum voltage is 9,350.

$$\textit{Ammeter reading} = \textit{maximum current} \times 0.707 = 60 \times 0.707 = 42.42 \textit{ amp.}$$

$$\textit{Voltmeter reading} = \textit{maximum voltage} \times 0.707 = 9{,}350 \times 0.707 = 6{,}610 \textit{ volts.}$$

Wrongly Installed Valves in Refrigeration Plant

By Thomas G. Thurston

Without warning, the relief valve on the ammonia compressor opened. The engineer stopped the machine before the ammonia fumes became too strong, and when they had cleared he could find nothing wrong. He started the machine, but the relief valve opened again, and he had to shut down.

The head-pressure gage gave no evidence of moving when the relief valve let go and apparently was out of order, though proved all right when tested. The gage line was not plugged.

The gage was connected to the purge line on the discharge header and the machine started. The pressure went up in jumps, and the compressor had to be stopped again. Evidently the discharge line was obstructed between the machine and the gage connection. There were three valves between the machine and the gage—the stop valve at the machine, the check valve and another valve at a cross-connection. Both stop valves were wide open, so he concluded that the trouble must be in the check valve.

The gage was replaced to the original connection, and he decided to pump the line out if possible. To his surprise, the line pumped out readily and the check valve was in order. The engineer opened the discharge stop valve, which of course has been closed while pumping out, and then opened the suction stop valve slightly to see if the gas would blow through into the discharge line and to the check valve, which still had the top off.

The gas escaped out of the check valve freely, showing that there were no obstructions. With many misgivings he removed the bonnet from the stop valve at the cross-connection and found that it had been put in the wrong way and that the disk had worked loose from the stem and dropped squarely on the seat, the flow holding it there, shutting off the line. When the line was pumped out, the flow was in the right direction through the valve, which explains why the pipe pumped down.

In another plant the oiler was surprised to find that the head pressure had jumped up about 30 lb. He had noticed the pressure a few minutes before and was positive it had been normal. He put more water on the condenser to get the pressure back to normal, but reduced it only a few pounds, although he had twice the normal amount of water going over the condenser. In addition the back pressure dropped several pounds and the machine ran hot. To get the back pressure down to normal and the machine to the proper temperature, he had to open the expansion valves much more than usual. These symptoms were just the reverse of what one would expect when the head pressure is raised. With an increased head-pressure, the feed through the expansion valves increases, the back pressure goes up and the machine gets too cold. Some time during the latter part of the afternoon the head pressure dropped 50 lb. The oiler, as soon as he noticed it, shut off some of the water and the machine froze, and the back pressure went up several pounds. This was again just the reverse of what would be expected. The head pressure was about 25 lb. less than it had been before it dropped, and still the

expansion valves were apparently feeding faster than before and they had to be readjusted to where they had been before the trouble started. The same thing happened several times during the following week. The engineer who erected the plant was sent for; the second day of his visit the pressure suddenly increased again. While getting at the purge valves, he heard a peculiar hissing sound in the discharge line at an angle stop valve.

The valve was open, though the engineer thought it was closed, as it should have been. It was found that the disk had worked loose from the stem. To have the flow in the valve in the proper direction, the stem should have been vertical, but the flow was against the top of the disk, tending to close the valve and force the disk off the stem. The disk had rattled and worked itself into such a position that at times it would be thrown against the seat and partly obstruct the passage through the valve. This is what raised the head pressure at irregular intervals; when the disk dropped back again, the pressure would decrease to normal. When the head pressure went up, all the water possible was turned on the condenser, which made the condenser pressure much less than normal and reduced the feed through the expansion valves, resulting in reduced back pressure and increased machine temperature. The reverse took place when the head pressure dropped again. The engineer cut down on the water to bring the head pressure up to normal; this raised the condenser pressure and increased the feed through the expansion valves, raising the back pressure and feeding such an excess of ammonia into the coils that large quantities of liquid escaped into the suction line and came back to the machine, "freezing" it.

What Draft Gages Tell

By M. K. Bryan

SYNOPSIS—A clear analysis of the effects of opening and closing the various dampers in a boiler furnace.

The interpretation of the reading of a draft gage connected to a boiler furnace is often erroneous. The most prevalent error is probably that of considering the reading a criterion of the combustion rate without due regard to other conditions.

The reasoning leading to such an interpretation probably is that if the damper is opened on a slow-burning fire the furnace draft is increased and the fire burns more rapidly, hence the greater combustion rate was a result of the increased furnace draft, so decreased furnace draft gives slower combustion. In reality, the greater air supply necessary for the more rapid rate of combustion was the result of the increased furnace draft. The decreased furnace draft after closing the damper was the cause of the reduced air supply accompanying the slower combustion rate.

The fact that a dirty fire burns more slowly and shows a higher furnace draft than a clean one is proof that the interpretation cited requires qualification.

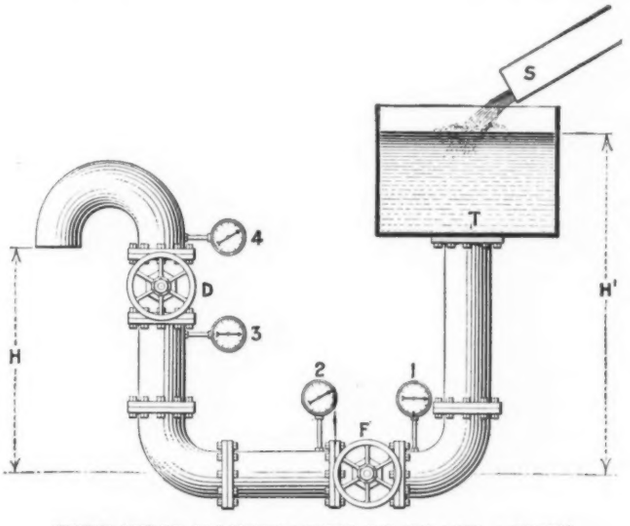
An attempt will be made to show what considerations are necessary to properly interpret the furnace draft-gage reading.

The combustion of a pound of fuel requires a definite amount of oxygen. The amount of air used (oxygen furnished) is usually in excess of that theoretically required. If we suppose this excess to constantly be 25 per cent. of the theoretically required quantity, then the amount used varies directly as the fuel burned, and the gases of combustion increase and decrease in quantity as the rate of combustion varies. In other words, increased rates of combustion mean increased quantities of air forced through the grate.

Draft is the pressure that forces this air through the fuel bed and the gases of combustion through the boiler and out of the stack. It is produced by the difference in weight of the column of hot gases contained in the boiler and stack and a column of outside air of greater weight than the column of hot gases.

This pressure is spent in overcoming the resistances offered by the grate and fire and by the boiler and stack to the flow of the air and gases, just as a head on a water system is used in overcoming the friction of the system.

For this comparison the arrangement shown by the illustration is sufficient. A tank T is fitted with a discharge line and supplied with water through a pipe S. The flow of water through the system is such that the head H is always the same. Valves D and F can be opened and



HYDRAULIC ILLUSTRATION OF DRAFT ACTION

closed as desired, thereby varying the resistance to the flow at these points. Friction is not considered.

The water flows from tank T because of the difference in loads H' and H. These heads are respectively analogous to the previously mentioned weights of outside air and hot gases in the boiler and stack.

The water flowing from tank T first encounters the resistance of the valve F, which corresponds to the fire and grate, then the resistance of the line connecting F and D must be overcome. This resistance is the boiler. The next resistance is the valve D, corresponding to the damper, and lastly is the resistance of the pipe beyond D. This resistance is comparable to the breeching and stack.

If the friction loss in the pipe beyond *D* is practically constant, only the resistances of *F* and *D* and the pipe between them need be considered. To overcome these there is then available a constant head slightly smaller than *H'* — *H*, and it is at once evident that the openings *D* and *F* will primarily control the quantity of water which will flow through the system. With fixed openings of *F* and *D* the head will produce a certain rate of flow and any change of these openings will be accompanied by a change in this rate.

Measuring the Draft Losses

Considering the opening of *F* to be constant, a clean fire of constant thickness and porosity, the rate of flow will vary as the opening of *D*, the damper.

As the opening of *D* is increased, its resistance decreases and the pressure which overcame the decrease of resistance is then available for use. In other words, more draft head is available to overcome the resistance of fire and boilers, and to establish a balance between the head and the resistance; the excess draft head increases the velocity of flow until the resistance added by the increased velocity is equal to the head released by opening *D*.

The resistance of the system exists by virtue of the velocity of flow through the system.

If with *D*, the damper, in a fixed position the opening of *F* is increased, reducing its resistance, i.e., if the fire is burned thin or a portion of the grate is bare, the total available head remains constant and the resistance is again increased by increasing the rate of flow until the total resistance and total head balance. Opposed to this is the closing of *F*, increasing the resistance by thickening the fire, by clinker sealing the air spaces in the grate or by changing the coarseness of the fuel. The total available head is still as great as before, but is not capable of forcing as large a quantity of gas through the added resistance. A balance is established by a decrease in the quantity of gas flowing.

No change occurs in the resistance of the boiler except from the change in velocity of the gases.

If ordinary pressure gages are attached, as indicated at 1, 2, 3 and 4, we can liken the readings of gages 2, 3 and 4 to those of draft gages connected respectively, over the fire, on the boiler side of the damper and on the stack side of the damper. Gage 1 will read the pressure *H'*, corresponding to the pressure of the atmosphere. Gage 2 will read less than gage 1 by the amount of head lost at *F*, corresponding to the pressure of the atmosphere less the resistance of the grate and fire. Gage 3 will read less than gage 1 by the amount of head lost at *F* and in the pipe beyond *F*, corresponding to the pressure of the atmosphere less the resistance of the grate, fire and boiler. The difference between the readings of gages 2 and 3 is the loss through the pipe, corresponding to the boiler resistance. Gage 4 will read less than gage 3 by the amount of head lost at *D*, corresponding to the damper resistance. It is seen that gage 2 indicates the resistance of valve *F*, or grate and fire, which is dependent upon the opening of *F* and the quantity of gas flowing, and it therefore serves no indication of either condition separately considered.

However, as an indication of the rate of combustion, gages 2 and 3 furnish the necessary information. It is the ratio of gage 2 reading to gage 3 reading that indicates the rate of combustion.

It was decided that as valve *F* was opened, valve *D* having a constant opening, the quantity of flow would increase to balance the decreased resistance at *F*. There would then be a less difference between gage readings 1 and 2—the furnace-draft gage reading would decrease and the reading of gage 3 remain practically constant. The ratio of gage 2 reading to gage 3 reading would decrease. The condition would reverse if *F* were closed. A less quantity would flow, and the ratio of the reading of gages 2 and 3 would increase. The point to be emphasized is the change in head available for causing flow through the boiler. Therefore, a decrease in the ratio of gage 2 reading to gage 3 reading indicates an increased rate of combustion, and an increase in this ratio indicates a decreased rate of combustion.

If, however, the opening of *F* is constant and *D* is opened or closed, the ratio remains constant, since then the resistance of the fire, as well as of the boiler, is dependent upon the velocity of flow, and the resistances will increase or decrease proportionally. If *D* is opened, the rate of flow, and hence combustion, is increased, and if *D* is closed the reverse occurs. In other words, with constant conditions of the fire under any boiler, the ratio of the furnace draft to the under-damper draft is constant for all values of the latter, and the greater the furnace draft the more rapid is combustion.

This fact concerning the ratio may be used to judge the condition of a fire as regards cleanliness or depth, when the size of coal fired and the completeness of combustion are the same at the times of comparison. If the conditions are unchanged, the ratio of furnace drafts to under-damper drafts will be constant.

Resistance of the Fire Varies

A change in fire resistance can be the result of several apparent causes, and therefore with the same setting of the damper the rate of combustion will change from time to time. For example, one day coal containing many small lumps and a high percentage of dust may be burned. To burn this, a certain damper opening is required and a corresponding furnace draft. Next day the coal burned may be coarser and contain less dust. The coarser fuel offers less resistance to the flow of air through it and therefore burns much more rapidly with the same damper setting than the fine coal. The under-damper draft is practically the same as when burning the fine coal, but the furnace draft is less. It is found that steam can be held with the damper choked; evidently, then, as much coarse coal is burned as there was fine coal on the previous day, and this is being done with a less under-damper draft and a less furnace draft. The drop through the boiler, however, is practically the same as when the fine coal was being burned. Furnace draft and undergrate draft must be considered together.

The fuel beds under two boilers may be equally clean and of equal depth and the rates of combustion be the same, and still the furnace drafts will differ.

Extreme causes will show clearly the lack of relation of furnace draft to the rate of combustion when this draft is considered independently of the under-damper draft. Compare a deep fire with a thin one. More furnace draft is required to burn the heavy fire than for an equal rate of combustion with the thin fire. The heavy fire may be increased in depth until it barely burns and the furnace draft will increase with the depth of the fire.

Editorials

Decomposition of Ammonia

This issue contains an abstract of what is perhaps the most satisfactory article ever written on the decomposition of ammonia in refrigeration plants. The article was originally published in the "Zeitschrift für die gasamte Kalte-Industrie," Berlin. The abstract was made from the translation as printed in the "Journal of the American Society of Refrigerating Engineers."

Although the decomposition of ammonia into its components, nitrogen and hydrogen, dilutes the refrigerant, causing gases useless for refrigeration to be circulated through the system, and decreasing efficiency, it is not because of this that decomposition is sufficiently important to warrant more thorough attention than has been, and now is, given to it by refrigerating men. It is because of the explosive character of the gases of decomposition under conditions which are possible in most refrigeration plants and which have not been anticipated and provided against that the subject is a vital one.

Ammonia as such is explosive only in oxygen. Of the gases of decomposition, nitrogen and hydrogen, only the latter is explosive. But there is not sufficient oxygen in the refrigeration system to make it explosive or even slowly combustible. As brought out in Professor Plank's article, experimenters have shown that the reactions bringing about decomposition of ammonia are rapid at high temperatures. Such rapid reactions liberate the hydrogen, which, on coming into the atmosphere, is furnished with oxygen with sufficient rapidity to quickly form a highly explosive mixture. It requires, then, for an explosion under operating conditions, first, the break liberating to the atmosphere the already-present gases of decomposition and the ammonia, and second, a flame or arc to ignite the explosive hydrogen of the decomposed gases, which by this time has formed with the oxygen of the air a highly explosive mixture. Perhaps our chemist friends can tell us whether or not, after the explosion has started, reactions could occur rapidly enough so that the heat generated would decompose the escaping ammonia, thus furnishing a supply of explosive, giving, as it were, a continued explosion. Ammonia explosions that have occurred in refrigeration plants indicate that these reactions do occur as rapidly as that.

Another source of hydrogen within the system is the lubricating oils, as told in the article on this subject of ammonia explosions, published in the November twenty-third issue of *Power*. The lubricating oils used in ammonia compressors have flashpoints not much above the discharge-gas temperatures in some plants, even when these temperatures are normal. The vaporizing oil then forms a hydrocarbon gas which, though highly explosive, would, it seems, be difficult to prevent without interfering with the function of the oil.

Catalytic action and impact of the gas during compression, particularly in high-speed machines, also the friction temperatures produced between the piston and the cylinder wall, are factors influencing decomposition. As Professor Plank points out, catalytic action cannot well be prevented in the compressor cylinder; but he suggests that as catalysis is active in the discharge pipe near the compressor, the pipe might be lined with porcelain, in contact with which ammonia gas is very slowly decomposed by catalysis.

Assuming that this would be worth while, the question arises, How much of the porcelain would chip off and give more trouble by getting on valve seats than it could prevent by minimizing catalysis?

There is evidence that high temperature without the effect of impact is productive of explosive gases, for almost any time one can ignite the gases issuing from the purge pipe of an absorption refrigeration machine. Apparently the only two factors tending to cause decomposition in such systems are temperature and catalysis.

The whole subject is important, and it is to be hoped that in the rapid advance of the refrigeration industry commercialism will not blind those in responsible positions to the necessity of minimizing explosions and consequent fire hazards.

Does Soda Produce Brittleness in Boiler Joints?

Among the papers of particular interest to *Power* readers, presented at the annual meeting of the American Society of Mechanical Engineers, that by Allen H. Babcock, of the Southern Pacific Railroad, on "A Novel Method of Handling Boilers to Prevent Corrosion and Scale," leads perhaps into the most important development of interest, although in itself merely an account of the discovery by the author of the exposition by Commander Frank H. Lyon, U. S. N., of the fact, already known, that pitting occurs when the contents are electro-negative to the containing vessel, and may be avoided by making the contents a solution of soda having an alkalinity of about three per cent. of normal. His successful use of the United States Navy compound, designed to effect this purpose, is the theme of Mr Babcock's paper.

It develops, however, that this panacea is not without its faults. Of two vessels of the Coast Guard Service the "Unalga" had a lot of boiler trouble, from which her sister ship, the "Miami," was immune. Upon investigation it was found that the "Unalga" had in eighteen months used thirty-three hundred pounds of the Navy compound, while the "Miami," which had had no trouble, had used only three hundred pounds. The order requiring the alkalinity to be in the vicinity of three per cent., based upon the reports of Commander Lyon, was rescinded, and the alkalinity cut down to about one-half or one per cent. On account of similar troubles, the same action was taken by the Navy. Attention was attracted to the prevalence of the same kind of trouble—the cracking of rivet heads and leaking of joints—in a limited district in Illnois, where the water was decidedly alkaline,

and in vessels used by the Solvay company in soda processes. Investigation undertaken independently by the Bureau of Engineering, the Chemical Laboratory at Annapolis, and the Babcock & Wilcox company are still in progress and inconclusive, but have shown that surprisingly large amounts of hydrogen can be occluded by steel plate, with the result that the plate becomes extremely brittle, and that caustic soda may become concentrated under butt straps or rivet heads to a degree necessary for the freeing, probably by electrolytic action, of nascent hydrogen. The matter has been investigated by Prof. J. H. Andrew, of the University of Manchester, who discussed it in a paper entitled "The Embrittling of Iron by Caustic Soda," to be found in the transactions of the Faraday Society for December, 1913. The subject is a most important and interesting one, and the results of the studies now in progress will be watched for with interest.

German Power Stations and the Present War

It is still too early to say how the war has affected electrical industry in Germany. However, already certain tendencies begin to show, which may become more pronounced as the war continues. Throughout Germany there has been an increased demand for lighting facilities other than those supplied by the use of kerosene, which has become very expensive, as a result of the small import and the large demand by the government as fuel. Consequently denatured alcohol is much in use and of course gas as well as electricity, where obtainable.

According to information collected by the *Elektrotechnische Zeitschrift*, of Berlin, it seems that the effects of the situation on electrical enterprise have varied according to local conditions. Some of the power stations, having both city and country districts to supply, have found that the demand for electricity for lighting has fallen away in the cities but has increased in the villages. In some cases electricity for lighting is being sold cheaply to families where the father is serving in the army, also military hospitals have received cheaper prices. While this appears to have had a beneficial influence on the sale of energy for lighting purposes, in many instances, several companies have found that the consumers are inclined to save, and consequently the sales to individual consumers have shown decreases.

The higher prices for coal have made the production of electricity in many cases more expensive. This has affected not so much the price for light, but rather for power. Consequently the price for energy for industrial purposes has increased in several places. All the industrial districts of Germany seem to be extremely busy, especially those where military supplies are made, and from all those districts reports come of increased activity in the power demand. For instance, the power station in Meseritz reports that it has so much to do with new extensions that the work cannot be completed as quickly as desired by the consumers, owing to the lack of trained hands.

Many of the power stations have followed the patriotic policy of not doing too much in their districts to increase the sale of electricity for lighting purposes where large gas-works are in existence. The German government wishes to increase the consumption of gas as much as possible during the war, as some of the byproducts of gas-making are needed for making explosives. Therefore the gas companies have entered into keener competition with the electrical stations and have succeeded in increasing their output. In Hanover the gas company, an English enterprise, has been taken over temporarily by the city and under the new management has introduced a great number of new selling methods, especially slot meters, which have been well received by the public.

Electrical extension of course has been hampered very much by the necessity of saving copper and other metals for the army.

Scale Thickness-Efficiency Ratios Again

Those who read the article, "The Internal Treatment of Boilers," in this issue will see the old statement that such and such a thickness of scale will increase the coal consumption so and so much. We have allowed it to stand, although we do not believe it.

As we have pointed out several times, the effect of blanketing the heating surface with scale will depend upon the ratio of heating to grate surface, the rate at which the boiler is run, the character of the scale, and so many other factors that any assumption that a given thickness of scale will have a certain effect upon the coal consumption would be so general as to be valueless even for argument.

Engineering Service Gratis

Not all engineers know that it is the usual practice of central stations to maintain a corps of engineers whose duty it is to make tests in isolated plants, determine what the power costs and what the cost would be if furnished by the central station. And this service is free to plant owners. Those who do not know this should, and those who do should not let it sink so deep in their minds as to forget it. For these reasons the author of this issue's leading article mentions the condition.

Some of our history is hazy, but we seem to recollect that there was once a king who, for fear that his purple splendor would make him forget he was but a mortal man, had an attendant frequently remind him of it.

Lap Seams in Massachusetts

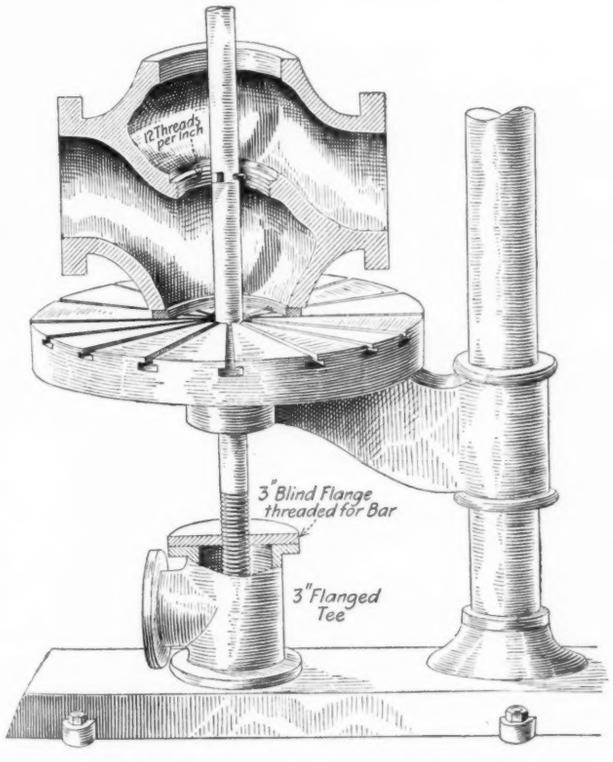
Chief George C. Neal, of the Massachusetts State Police, has sent a circular to all boiler inspectors reminding them that the law provides that all boilers shall be thoroughly inspected internally and externally, and that if the covering and brickwork have to be torn to pieces in order to get at vital parts of the boiler, such as longitudinal seams, in order that such inspection may be made, the tearing up will have to be done. It is to be expected that this will raise a howl of indignant protest, but Massachusetts has suffered sufficiently from lap-seam explosions to warrant especial carefulness in their regard, and owners of lap-seam boilers should welcome this thorough inspection as an assurance of the immunity of their own boilers from incipient rupture and as a welcome substitute for the more drastic legislation, which is not without its proponents, that the lap-seam boiler be denied the further right of existence in the commonwealth.

Correspondence

Recutting Valve-Seat Threads on the Drill Press

A 6-in. extra-heavy throttle valve on our 500-kw. Curtis turbine developed a bad leak. Examination showed the leak to be between the valve proper and the seat. The threaded portion was in such bad condition that rethreading was necessary.

Our 20-in. lathe would not swing the valve, so the drill press was resorted to in the following manner: The valve was set up and a heavy boring bar used to clean out the old thread. The bar was then removed and the end threaded for about 4 in., the thread being 12 per inch to correspond with that of the new seat. A 3-in. blind flange was then threaded to fit the bar. A 3-in. flanged tee was bolted to the base of the drill press, with the



THREADING 6-IN. THROTTLE VALVE

blind flange bolted to one end, all being central with the bar. The feed on the spindle was disconnected and the bar was entered in the flange a distance of about 1 in., to get the proper location of the tool which was of ⅝-in. square tool steel.

A Rockford 26-in. press, with back gear, was used, and an excellent thread resulted.

While this method of doing such work is an improvised one, the ready manner in which it was applied and the thoroughly satisfactory results suggest a more general application.

E. B. Simpson.

Waukegan, Ill.

Some Causes of Gas-Engine Trouble

The successful operator uses reason in the care of his engine. He is interested in it and its work; for the man who removes every pound and keeps the engine in good adjustment will have little trouble. Think over the repair before it is started, and the worst part of it is done. Do not take the magneto apart only to find that the fuel is not properly supplied. It is a good plan to have a regular schedule and go through it before putting a wrench on the engine, unless certain as to the cause of the trouble.

If the engine has a pound, look for the following causes: Loose crankpin bearing. Loose main bearing. Loose piston-pin bearing. Loose or worn piston. Parts out of line. Early ignition or preignition. Motor loose on foundation or frame. Cylinder loose on base or crank case.

Any of the following may cause irregular running: Governor worn or dirty. Governor belt loose. Governor mechanism out of order. Fuel supply uncertain. Ignition uncertain. Clutch or drive belt slipping.

Look for the following causes if the engine is hard to start: Cylinders flooded. No fuel in carburetor. Water in carbureter or cylinder. Low-grade fuel. Poor compression. Engine too cold for fuel to vaporize. Ignition system in bad order.

Overheating may result from one of the following common causes: Lack of cooling fluid. No circulation of cooling fluid. Rich fuel mixture. Lean fuel mixture. Preignition. Late ignition. Exhaust passages filled up.

Any of these conditions may cause lack of power: Poor fuel mixture. Poor compression. Valves out of time. Valve springs weak. Ignition system out of order. Low-gravity fuel. Lack of lubrication.

While the foregoing does not include all the things that may occur with a gas engine, it gives some of the principal reasons for gas-engine trouble.

Charles City, Iowa. C. V. Hull.

Paper Mill Power Plants

The correspondence relative to paper-mill power plants has interested me, as my work has permitted me to visit many of the large mills throughout the northern part of this country and some in Canada.

Few engineers not familiar with paper-mill power plants realize the size of some of them and their important relation to paper-making. This is best illustrated, perhaps, by the fact that about 30 per cent. of the cost of paper is power charge. Only one or two other industries require an equal horsepower per employee. It is therefore quite usual to find paper mills near water-power developments where cheap power is available. Another reason for locating near water is the extensive use of water in the process.

It is necessary to remove the water from the paper by evaporation, and the extensive use of steam for this purpose makes it economical to operate steam engines and steam turbines, as the power is practically a byproduct of the steam drying plant and the engine is useful as a reducing valve. Furthermore, in making high-grade papers uniformity of speed is essential and must be maintained throughout a wide range of speed changes, and the steam engine is capable of close speed regulation under variable loads.

Perhaps it is safe to say that no other industry can show so large a percentage of plants that use both water power and steam power, and in many of these plants the waterwheels and steam engines are operated together, driving the same mainshaft.

The introduction of electric power has been attempted, but its principal use at the present time is in the various finishing operations—very few mills having attempted to drive the paper machine proper with motors. Some claim that they have met with success, but I know of one mill where motors have been removed to give place again to the "old reliable" steam engine. In this particular case the power was purchased from a central station and speed variations occurred beyond the control of the mill management. Even where the electric power has proved satisfactory, it is difficult to see that advantages are gained to pay for the large additional investment required.

One old "rule-thumb" paper-mill standard is the production of one pound of paper for each pound of coal burned under the boilers. This standard was probably imported from England and originated at a time when paper was made in almost the same way throughout the trade, and it really represented excellent fuel economy and careful recovery of exhaust-steam returns. Some managers still use this standard, even though many processes have been revolutionized and many different types of prime movers are used. I know of one mill that is highly efficient mechanically by a large investment, but the commercial efficiency has suffered because the costly apparatus entails such heavy fixed charges that the saving in fuel charges is more than offset.

Some paper mills have power plants aggregating five or six thousand horsepower operating 24 hours a day for 6 days a week, and this enables them to show better economy than many central stations. A description of some of these plants and their problems would make interesting reading. W. F. Rockwell.

Boston, Mass.

Sudden Cooling of Overheated Boiler Plates

I have read with much interest R. M. Blackburn's article on this subject in the Nov. 16 issue, page 696. While I know that his advice is contrary to the generally accepted procedure in such cases, I believe that if the truth were known, many engineers practice what Mr. Blackburn advocates. I confess that I have cooled red-hot plates by admitting feed water to the boiler, and so far as I could discover no harm was done. However, there is no question that low water in a boiler is dangerous and should be guarded against. Perhaps if the plates of a boiler were to be overheated but once or twice in its lifetime and quickly cooled by flooding the plates with feed water, no harm would be done. But it would seem that many repetitions in a comparatively short time of this flooding, or sudden cooling, process might be dangerous to the plates, in spite of the fact that they are made to rigid specifications, as stated by Mr. Blackburn.

Besides turning the cold feed water on to the hot plates, the fire should be deadened or drawn.

Mr. Blackburn's method is indeed a most excellent expedient, but I believe that young engineers particularly should be taught that low water in a boiler is one of the most dangerous things that can happen to them, and they should be made to dread it and avoid it as one would avoid a bomb with a lighted fuse. The principle is the same in both cases. A bomb with a lighted fuse might be thrown into a crowd or near a single person, and with due presence of mind and judgment as to the time it would take the fire to reach the interior, one might run to the fuse, pinch it, extinguish the spark and come off safe. But this is all a matter for the individual to decide. Seeing the burning fuse, noting its length, measuring the distance and knowing the quickness and precision of one's own movements, are some of the things one would have to consider.

Attica, Kan. Philip Ream.

Taper Keys Were Inverted

Some time ago we had a breakdown with a 2,000-hp. two-crank, triple-compound horizontal engine, with three cylinders in tandem, the low-pressure being nearest the crank, then the intermediate-pressure and then the high-pressure. The piston rods were in two parts coupled between the low-pressure and the intermediate-pressure cylinders by a gib and key, and all of the pistons were taper fitted and secured by keys.

Sudden priming at the boilers caused a severe pounding at the main engine, which was promptly shut down. When one of the high-pressure cylinder covers was taken off, the key was found to be missing and the piston off the rod. As the wide part of the key was at the lower side of the rod, in all probability the slug of water had driven the piston further up on the taper on the rod and loosened the key, which fell out of its place and was shot into the escape-valve passage, fortunately avoiding more serious damage. The key holding the intermediate piston was also wrong, because the coupling between the two rods had been reversed and this had brought all of the keys upside down. It is not known how long the engine had been operated in this condition, but without doubt a long time.

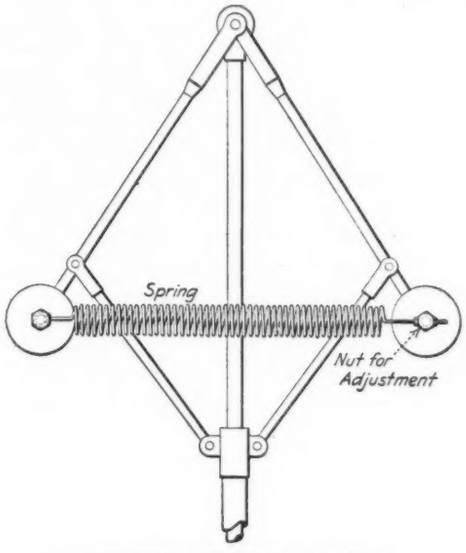
Will some of your turbine engineers give us the benefit of their experiences in blading troubles? We have had a lot of difficulty with steel blading corroding and have changed some reaction blading to bronze, in an attempt to avoid the trouble. A few weeks ago we had a case of blade stripping. The blading was of a bronze alloy, and several stationary blades just opposite to where the gland leak-off entered the casing, broke and damaged the moving blades next to them. This is the second time this has happened, and we are at a loss to account for it. As turbines are being widely adopted, it would no doubt benefit engineers if turbine men would give the readers of *Power* an account of the troubles they have diagnosed, treated and cured. W. Maclean.

Glasgow, Scotland.

Corliss Engine Cured of Racing

We have a 26x48 Corliss engine direct-connected to a 500-kw. generator, on which the load is very unsteady, heavy machinery being thrown on and off frequently, so that the governor, of the slow-speed (50-r.p.m.) flyball type, would not hold the engine anywhere near steady.

We replaced the 28-in. pulley on the governor with a 14-in. pulley, then drilled and tapped the balls on each side for ⅞-in. capscrews. From one ball to the other



TENSION SPRINGS ADDED

on each side we put springs made from No. 6 brass wire with an adjustment to regulate the tension.

Before making this change the variation was 20 to 25 volts, but now 5 or 6 volts is the limit. The illustration shows how the springs were attached.

South River, N. J. JOHN MORLOCK.

Observations While on the Road

In my travels through the country selling steam supplies I have observed a tendency on the part of both managers and engineers of power plants to arrive at the cost of power production more accurately. Where the manager is interested it is a fairly easy matter for the engineer to get the necessary supplies and appliances, but where the office cannot see the light, some engineers exercise considerable ingenuity to make them "come across."

In one plant I saw a revolution counter connected on the boiler-feed pump, so as to indicate every stroke of the pump. The counter is set back to zero every shift, and as they keep track of the coal consumed, they also have an idea of the water evaporated per pound of coal. I do not believe they get very accurate figures, but there is a rivalry created among the firemen to make the best showing, and the firm is certainly the gainer.

But on the other side, in another plant I found the engine shut down. I asked the chief how it happened, as his employers use a great deal of lumber and have considerable waste to burn, also have dry kilns which are operated continually throughout the year. He stated that a central-station expert convinced the management that it could furnish power cheaper than the plant could make it. The boilers and engine were for sale, and they were going to put in a low-pressure boiler for heating. I asked if he had any figures to check against the central station and if he had the necessary apparatus to make tests to find the cost of power developed. He said he had a water meter, but did not have the time or help necessary to make tests.

In this case the plant was fairly modern, but the engineer had put the skids under himself. If he had taken the trouble to run tests a number of times a year and had kept records, no fast talker from the central station could have talked him out of a job. I cannot see how the central station can furnish power as cheaply as this concern was making it, using exhaust steam to heat buildings and kilns, especially as considerable of the fuel was waste lumber.

There will be "something doing" here inside of a year if I don't miss my guess. C. W. FRANKLIN.

Brooklyn, N. Y.

Emery Ruins Gas-Engine Valves

The letter, "Emery Ruins the Cylinders of a Compressor," on page 657 of the Nov. 9 issue, reminded me of a similar case of bull-headed engineering. A man who thought he knew how to handle gas tractors bought one for a big farm in Dakota. The type which he purchased had a kerosene motor, and water was admitted to soften the pounding, according to the usual practice.

The water was strongly alkaline, and the salts deposited on the stems of the exhaust valves. This deposit caused the valves to act sluggishly and even stick.

This man had to take out the cages and clean the valve stems a number of times—an unpleasant job, for the scale on the stems is very hard and sticks almost as if it were a part of the stem; yet many operators in that section have become so accustomed to cleaning the scale from valve stems that they think nothing of it. But this owner, tired of removing the cages so often, hit upon a scheme to prevent the scale formation by packing the stems with a mixture of emery and grease. This ended the scale trouble, but caused a more serious one; for the stems and guides were cut by the emery until the valves did not seat properly. This of course meant loss of compression and lack of power.

Realizing that something was wrong, the owner sent for an expert, who soon located the trouble and ordered a new set of valves and cages. Besides, he advised the use of soft water or the substitution of gasoline for kerosene, so that water would not be needed.

One manufacturer of this type of motor has reduced the diameter of the valve stem where it travels back and forth at the inner end of the guide; the outer end of the stem fitting snugly and holding the valve in line. With this arrangement a considerable amount of deposit may form before the valve action is affected.

The amount of ignorance and carelessness regarding the cutting qualities of emery is surprising. Frequently I have seen men grinding the admission valves without giving any attention to the waste or excess emery or grinding compound. In many cases this grinding material

falls into the valve chamber and stays until the motor is assembled. Then the suction draws it into the cylinder, where it cuts. C. V. HULL.

Charles City, Iowa.

Firemen's Bonus Successful

The purpose of this letter is to illustrate a case where the bonus paid to the firemen for lowest coal consumption proved successful. The boiler room of this power plant, situated in New England, consists of four 400-hp. boilers with hand-fired furnaces. The coal used is bituminous, having a heating value of 14,500 B.t.u.; 6 per cent. ash.

The general opinion until about a year ago, when a crusade was started to reduce operating expenses, was that the plant was being operated as economically as possible. Up to that time the average evaporation was 9 lb. water per pound of coal, or about 60 per cent. combined efficiency, which was good for continuous operation and a fluctuating load. The coal burned was between 12 and 15 lb. per sq.ft. per hr.; the intervals between firing were about 7 min. The fires were maintained about 10 in. thick.

When the data was being compiled it was found that the CO_2 ran high, about 13 per cent. average, and that there was also CO, due to heavy fires and firing when the damper regulators had the dampers closed. The loss resulting from this practice was twofold—the loss of an immense amount of potential heat contained in the CO and volatile matter which was driven off and not allowed to burn, and the loss due to this carbon accumulating on the heating surfaces of the boilers and affecting the transmission of heat. Thermometers were placed in the superheater lines, and it was discovered that instead of 100 deg. F. superheat there was only 13 deg. An examination of the superheaters disclosed the reason. The tubes were completely covered with soot varying in thickness from ⅜ to 1 in. These tubes were cleaned and a few air leaks around them stopped up. The superheat was then 100 deg.

The effect of firing with dampers closed, dirty heating surfaces, too heavy fires, varying water level, and a few other minor details were pointed out and soon appreciated by the boiler-room men. It did not seem advisable at this time to purchase a CO_2 recorder, but instead gas collectors were installed on each boiler and collected the samples for each eight-hour shift. A bulletin board in the boiler room showed each day the kilowatt output, coal used and average CO_2 for each shift. For some time one man invariably had the highest CO_2 and also the highest coal. This was found to be due to too heavy fires. Since this was corrected the highest CO_2 is usually concordant with the lowest coal.

The firemen soon saw the good results of their efforts and are now careful to do the things which they formerly considered unimportant. The records began to show that the cost of coal per kilowatt was on the decline, but it was still troublesome to keep the boilers in first-class condition and the methods of firing up to standard.

A bonus system was put into effect whereby the fireman with the lowest coal, based upon the same shift with the others for a period of six weeks, received 15c. per day extra in his pay envelope. Every two weeks one of the three firemen receives a bonus of $2.10. The boiler operation at this plant now is such that it can scarcely be criticized. The result has been a substantial reduction of, in round numbers, 20 per cent. in boiler-room costs since this plan has been effective.

The redeeming and unusual feature of this has been the absolute lack of any friction or enmity and the establishment of undisputed confidence in the veracity of the boiler-room personnel.

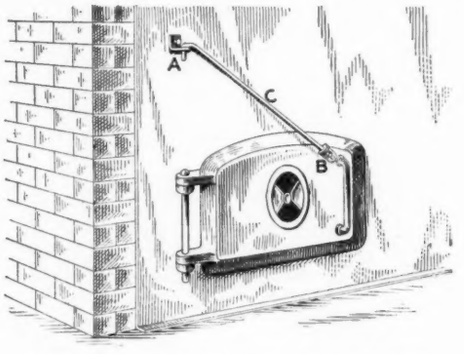
CHARLES M. ROGERS.

Meridian, Miss.

Old Fire-Doors Made Usable

Fire-doors are difficult to keep closed tightly when the holes in the hinges become worn, and allow the opposite end of the door to sag. A row of furnace doors showing a red glare through the openings, having props or other makeshifts to keep them shut, presents an unsightly appearance. Sometimes, larger holes are drilled in the hinges and, by inserting larger pins or bushings, the old doors are brought back to their original position, but this will not be permanent.

A simple method that any engineer can apply is shown in the illustration. An angle iron *A* should be fastened



SUPPORT FOR SAGGING FIRE-DOOR

to the furnace front about 12 in. above the door hinge on a line perpendicular to the center of the hole in the hinge. Another angle iron *B* should be fastened to the fire-door and the rod *C* inserted and fastened by tightening the first nut enough to lift the door to the right position; then the second nut can be tightened to lock it. The size and strength of the parts should be proportioned to the weight of the door. C. E. KLING.

Philadelphia, Penn.

Machining Piston Rings

I would like to have some more discussion on the subject of machining piston rings by readers of *Power* who have had engine-building and repairing experience. H. R. Low states in the issue of Aug. 31, page 312, that "if once the scale on the inside or core is removed much of the spring and half the life of the iron are gone."

If this is true it would seem that engine makers would consider it worth while to so core the ring castings that boring would be unnecessary even though it would be somewhat more expensive. I have never heard that any engine builder did so. It seems a good subject for profitable discussion. J. M. COLEMAN.

Somerville, Mass.

Inquiries of General Interest

Effect of Adding Lap to Valve—What is the effect, if any, on the lead, point of cutoff and the port opening from increasing the lap of a plain slide valve, the valve travel and angular advance of the eccentric remaining unchanged.
M. H. C.

Adding lap without other changes results in later admission, earlier cutoff and less port opening.

Wiredrawing Steam Will Wear Valves—Does wiredrawing steam tend to injure valves? L. L. S.

Wiredrawing steam, as when it is discharged from a higher to a lower pressure through a partly closed valve, is accompanied by a high velocity of the steam, which results in abrasion or cutting of the valve surfaces. The wear is to be attributed to friction and impact of the initial steam against the valve surfaces and is greater with wet than with dry initial steam.

Formula for Heat Value of Coal—Knowing from analysis the percentage of carbon, hydrogen, oxygen and sulphur present in a given sample of coal, how is the heat value computed?
W. R. N.

Dulong's formula for the heat value, or number of B.t.u. per pound, of coal is

$$\text{B.t.u. per lb.} = 14{,}600\,C + 62{,}000\left(H - \frac{O}{8}\right) + 4{,}000\,S$$

In the formula C, H, O and S are proportionate parts, or per cent. by weight of carbon, hydrogen, oxygen and sulphur respectively.

Drainage of Main Steam Piping—How should the drainage of main steam piping from boilers to an engine be provided for? F. H. L.

Each boiler stop valve should be so arranged that all condensation forming between it and its boiler will drain back into the boiler, and the piping should slope beyond the valves so that water will drain away from the boilers toward the engine. When several boilers are connected to a header, the condensation between the stop valves and header may be drained into the header and the header may be drained by means of a bleeder pipe.

Hard Coatings in Boiler Flues—What causes the tubes of a horizontal return-tubular boiler to become covered on the fire side with a hard soot coating? G. L.

The coating may be a deposit of unburned hydrocarbons driven off from the fuel by the heat of the furnace, but condensed upon coming in contact with the lower temperature of the tube surfaces; or may be due to the use of wet fuel in raising steam from a cold boiler; or may be due to cleaning the tubes with a steam flue cleaner when the boiler is so cold that the steam condenses and causes the soot to gum and form a hard coating after becoming dry.

Pumpage Expressed in "Winchester Gallons"—The stroke of a center-packed double-acting duplex plunger pump is 12 in., the plungers are 10 in. diameter, and the number of strokes for both pistons is 40 per minute. What will the pump handle in Winchester gallons per hour? C. M.

The plunger displacement per stroke will be $(10 \times 10 \times 0.7854) \times 12 = 942.48$ cu.in. and per hour would be $942.48 \times 40 \times 60 = 2{,}261{,}952$ cu.in. A Winchester gallon (which is an obsolete term for one-half peck) is 268.8025 cu.in., and therefore the pump without allowance for slippage would handle $2{,}261{,}952 \div 268.8025 = 8{,}414.9$ Winchester gallons per hour.

Power from Indicator Diagrams—The piston of an engine is 19 in. in diameter and the piston speed is 480 ft. per min. The average ordinate of indicator diagrams taken with a 40-lb. spring is 1.16 in. What was the indicated horsepower?
S. J. C.

The area of a piston 19 in. diameter would be $19 \times 19 \times 0.7854 = 283.53$ sq.in. As the average ordinate of the diagram taken with a 40-lb. spring is 1.16 in., then there would be $1.16 \times 40 = 46.4$ lb., m.e.p., and with a piston speed of 480 ft. per min. there would be a development of $283.53 \times 46.4 \times 480 = 6{,}314{,}780.16$ ft.-lb. per min., or $6{,}314{,}780.16 \div 33{,}000 = 191.35$ i.hp.

Discharging Exhaust Steam in Chimneys—What objection is there, if any, to turning exhaust steam into a chimney?
W. D.

Usually, exhaust steam tends to choke the draft when turned into a tall chimney and the steam, becoming chilled before reaching the top of the flue, is converted into a condensate that runs down the insides, to be absorbed by the walls of the chimney or again partly reëvaporated by absorbing the heat of the escaping gases, thereby neutralizing their buoyancy by reducing their temperature. Moisture thus introduced in an iron or steel stack rapidly corrodes it or soon destroys the material of brick chimneys.

Principal Events of the Stroke—In the operation of an engine having a plain D slide valve, what is meant by the principal events of the stroke and when do they occur?
J. C. R.

The term "events of the stroke" usually has reference to the distribution and control of steam in an engine cylinder as determined by the action of the valve. The principal events are "admission," "cutoff," "release" and "compression." When the outside edge of the valve is at the edge of the steam port and the valve is opening, admission is said to occur, and the amount of port opening before the actual commencement of the stroke is called lead. When the valve is again in the same position but is closing, cutoff takes place. Release occurs when the inside edge of the valve is at the edge of the exhaust port and the valve is opening to exhaust, and compression occurs when the valve is again in the same position but is closing the exhaust.

Required Thickness of Boiler Shell—When the tensile strength of the material, diameter of shell, efficiency of longitudinal joint, factor of safety and safe working pressure of a boiler are given, what would be the formula for the thickness of shell? E. B. N.

Where

S = Tensile strength of shell plate in pounds per square inch of cross-sectional area;
t = Thickness of plate in inches;
E = Percentage of efficiency of longitudinal joint;
F = Factor of safety;
D = Diameter of shell in inches;
P = Safe working pressure per square inch;

then considering 1 in. of length of the longitudinal joint,

$$1 \times t \times S \times E \times 2 = 1 \times D \times P \times F$$

and therefore the value of t, the thickness, is given by the formula

$$t = \frac{D \times P \times F}{S \times E \times 2}$$

Hp. Constant and Development of I.hp.—If 19.5 lb. m.e.p. is developed in a 12x16-in. engine running 200 r.p.m., what would be the horsepower constant and indicated horsepower?
N. E.

The horsepower constant is equal to the power developed by 1 lb. m.e.p., hence in the ordinary formula for the number of horsepower, namely,

$$\text{Hp.} = \frac{PLAN}{33{,}000}$$

P = 1, and by substitution, Hp. constant $= \dfrac{1 \times L \times A \times N}{33{,}000}$

where

L = 16 in., or $1\frac{1}{3}$ ft.;
A = Area of piston, or $12 \times 12 \times 0.7854 = 113.1$ sq.in.;
N = 200×2 or 400.

Then by substituting, it is found that

$$\text{Hp. constant} = \frac{1\frac{1}{3} \times 113.1 \times 400}{33{,}000} = 1.828 \text{ i.hp.}$$

and with 19.5 lb. m.e.p. the engine would develop $19.5 \times 1.828 = 35.65$ i.hp.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Good Showing of Cleveland Municipal Plant

SYNOPSIS—The first cost of the generating plant was $56.869 per kilowatt capacity, and the total cost of the system, including substations and distribution lines, $117 per kilowatt. The average production cost at the switchboard for the first eight months of 1915 was 0.375c. per kw.-hr.

In a recent bulletin dealing with the Cleveland municipal lighting plant, F. W. Ballard offers conclusive operating and cost figures to prove the success of the undertaking and answers a number of the criticisms made by the Cleveland Electric Illuminating Co. through the publicity channels of the National Electric Light Association.

This station, it will be recalled, has a rated capacity of 20,000 kw. and the unit first cost, exclusive of land and distribution system, was $51.260 per kilowatt, or with the land $56.869 per kilowatt. This was made up as shown in Table 1.

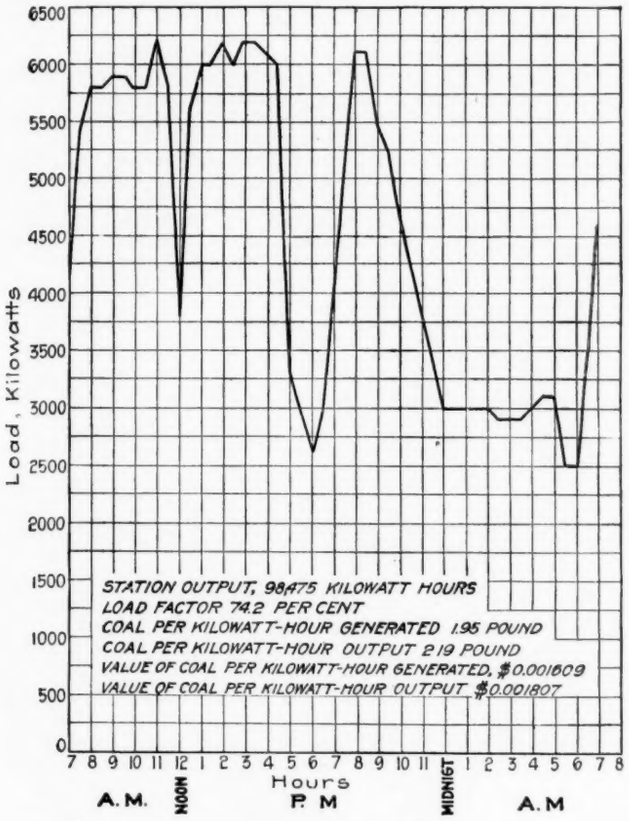


FIG. 1. TYPICAL LOAD CURVE

The four substations, with a capacity of 16,500 kw., cost $194,996.50, or $11.818 per kilowatt; the distribution system and service lines, $1,090,380.43; miscellaneous items, $41,138.87; making a total of $2,351,881.88, or approximately $117 per kilowatt of station capacity.

Table 2 shows the generating costs for the first eight months of the present year and also for August, 1915. It will be seen that the average cost for coal per kilowatt-hour for the eight months was $0.002⅛, while for the month of August it was $0.0019. The total generation cost for the eight months was $0.00375 per kw.-hr. and for August, only $0.00325.

For 1912 the average distribution cost was $0.00448 per kw.-hr. generated; for 1913, $0.00408; and in 1914 this was brought down to $0.00361 per kw.-hr. Table 3 gives the revenue and expense statements for the first eight months of 1915.

In this connection it might be mentioned that the total customers number 14,500, of whom 200 are responsible for the day load, the day load being about twice the night load. A typical daily load curve is reproduced in Fig. 1. The load factor, based on the maximum load of slightly over 6,000 kw., ranges from 60 to 70 per cent., although the plant factor, based on installed capacity, would be only about one-third of this. The revenue from power and commercial-lighting service is divided in the proportion of 55.3 per cent. for power and 44.7 per cent. for commercial lighting.

TABLE 1. COST OF MAIN GENERATING STATION AT EAST FIFTY-THIRD ST.
To Sept. 1, 1915

Item	Cost	Cost per Kw.
Aqueduct for water supply	$22,971.43	$1.149
Excavation	32,456.81	1.623
Concrete piling	32,142.04	1.607
Foundations	84,378.77	4.219
Structural	73,211.39	3.661
Building above foundations	83,004.84	4.150
Flues, dampers and gratings	34,364 27	1.718
Chimney	3,945.00	.197
Boilers and settings	90 000.12	4.500
Stokers and equipment	45,845.07	2.142
Forced-draft equipment	12,108.00	.605
Economizers and induced-draft equipment	36,198.46	1.810
Coal and ash-handling equipment	19,659.21	.983
Auxiliary and miscellaneous machinery	33,402.57	1.670
Turbo-generators	147,258.19	7.363
Condensers and equipment	45,760.72	2.288
Piping	60,662.67	3.033
Switchboards and electrical work	89,540.62	4.477
Crane	5,273.08	.264
Special instruments	4,071.96	.204
Acceptance tests	9,044.57	.452
Land betterments	8,344.04	.417
Construction buildings (temporary)	186.58	.009
Railway siding	2,900.00	.145
Engineering and superintendence	51,665.67	2.583
	$1,025,396.08	$51.269
Land (not paid for from bond money)	112,000.00	5.600
	$1,137,396.08	$56.869

TABLE 2. EAST FIFTY-THIRD STREET POWER-PLANT REPORT

	August, 1915 Total Cost	August, 1915 Unit Cost	Year 1915 to Sept. Total Cost	Year 1915 to Sept. Unit Cost
Boiler- and engine-room service	$2,341.68		$18,643.13	
Switchboard attendance	440.00		2,883.33	
Total service	$2,781.68	$0.001084	$21,526.46	$0.001339
Lubricants	$17.38		$200.60	
Packing and waste	33.89		158.38	
Water	.....		126.44	
Tools	.....		1.97	
Miscellaneous hardware supplies	.....		298.25	
Cleaning and toilet supplies	3.53		52.67	
Total sundries	$54.80	$0.000021	$838.31	$0.000052
Maintenance				
Grounds	$34.64		$54.08	
Buildings	.....		21.04	
Boilers and settings	135.63		1,029.63	
Stokers	140.22		$49.96	
Coal and ash equipment	20.61		213.00	
Condensers and piping	101.53		232.50	
Auxiliary and miscellaneous machinery	27.01		615.54	
Engines and prime movers	.40		35.63	
Generators	.....		366.59	
Switchboard	.....		301.64	
Special instruments	14.72		15.97	
Tools	.....		95.02	
Aqueduct	.....		34.52	
Total maintenance	$474.76	$0.000185	$3,865.12	$0.000240
Fuel used, weight	3,038.929 T.	2.364 lb.	19,493.424 T.	2.426 lb.
Cost per ton	$1.667			
Amount	$5,065.89	$0.001974	$34,205.33	$0.002129
Total generating service expense	8,377.13	0.003264	60,435.22	0.003761
Total kw.-hr. at switchboard	2,565,900		16,068,710	

One rate schedule applies to all classes of service; that is, it makes no difference whether the energy is used for power or for lighting. The maximum rate is 3c. per kw.-hr., and the minimum is a little over ½c. per kw.-hr. The rate chart is reproduced in Fig. 2. The intersection of the vertical lines representing kilowatt capacity of the service connection with the horizontal lines representing the kilowatt-hours used gives the rate for that month, as shown on the diagonal.

In this connection the following excerpt from Mr. Ballard's report relative to the old Brooklyn station is pertinent:

The output in kilowatt-hours for the first eight months of 1913 was practically double the output for the first eight months of 1912, and while the revenue was increased from $89,000 to $115,000 and the average sale price was lowered from 3.2c. to 2.63c., yet the operation and maintenance was increased only from $48,000 to $64,000 and the average cost price was lowered from 1.73 to 1.45c. Furthermore, notwithstanding the fact that nearly all of this current which was sold to factories for power in order to fill in this valley was sold at a rate of 1c. per kw.-hr. with our average cost price

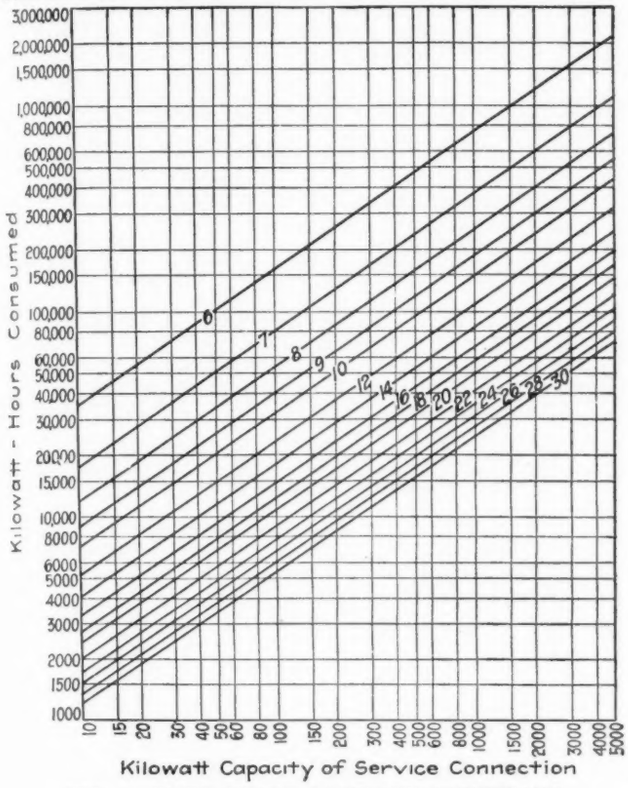


FIG. 2. RATE CHART IN USE BY CLEVELAND MUNICIPAL PLANT

TABLE 3. REVENUE AND EXPENSE STATEMENT FOR FIRST EIGHT MONTHS OF 1915

Total revenue from sale of current, Jan. 1, 1915, to Aug. 31, 1915	$313,800.38
Kw.-hr. generated, 16,846,250. Average sale price, $0.0186.	
Kw.-hr. sold, 14,981,595. Average sale price, $0.0209.	
Total operation and maintenance for period Jan. 1, 1915, to Aug. 31, 1915	181,735.28
Kw.-hr. generated, 16,846,250. Average cost price, $0.0109.	
Kw.-hr. sold, 14,981,595. Average cost price, $0.0121.	
Net earnings	$132,065.10
Fixed charges, sinking fund and interest, Jan. 1, 1915, to Aug. 31, 1915	125,275.28
Kw.-hr. generated, 16,846,250. Average cost price, $0.0074.	
Kw.-hr. sold, 14,981,595. Average cost price, $0.0083.	
Profit for first eight months of year 1915	$6,789.82

running at 1.73c., yet the effect of this very thing was to bring down the average cost price to 1.45c., and the net receipts of $41,000 for 1912 were increased in 1913 to $51,000. We therefore increased our profits in 1913 by $10,000 over what they had been the year before, and did it by selling at 1c. per kw.-hr. current that had previously cost us about 1.75c.

Correction in Rate Schedule—In the July 6 issue appeared a "Comparison of Electric Light and Power Rates," by Judson C. Dickerman, which was based on the author's investigations for the Department of Public Works, Philadelphia. It develops that there were two or three slight errors in the original data. Referring to Table 2, page 12, for commercial lighting, the maximum demand should have been 75 per cent. of the installation instead of 80 per cent. In the same table the Providence tabulation for the case of 100 kw.-hr. consumption should read 20.25c. and $20.25 instead of 10.90c. and $10.90 respectively; for the case of 400 kw.-hr. consumption it should read 6.19c. and $24.75 instead of 3.85c. and $15.40 respectively. Consequently the Providence curve in Fig. 2 is incorrect. The data for the correct curve are as follows:

150 kw-hr. consumed per month	14.00c.
200 kw.-hr. consumed per month	10.87c.
300 kw.-hr. consumer per month	7.75c.
400 kw.-hr. consumed per month	6.19c.
500 kw.-hr. consumed per month	5.25c.
600 kw.-hr. consumed per month	4.62c.

NEW PUBLICATIONS

CORROSION OF IRON. By L. C. Wilson. Published by the Engineering Magazine Co., New York, N. Y. Size, 5¼ x 8⅝ in.; 178 pages. Price, $2.

The problem of rust and corrosion in connection with our great steel structures has occupied the attention of many engineers recently, and we are particularly indebted to the work performed by the Government and by paint manufacturers. In this book the author has collected some of this material in a condensed form with the idea that it would give a good understanding of the subject for the busy engineer. Under the theory of corrosion, the three principal theories are given with the evidence for and against. In the chapter on general protective measures, the author covers fairly well most of the methods that have been applied in the form of coatings, such as oxide, coatings of other metal and coating with paint or similar material. Naturally the book contains a large amount of matter on paint materials and the relative values of the different pigments and oils. This condensed review of the subject forms a useful addition to the engineer's library and will be of decided value to those interested in paints and other protective devices.

THE INTERNAL COMBUSTION ENGINE. Second edition. By H. E. Wimperis. Published by D. Van Nostrand Co., New York, 1915. Size, 5½x8½ in.; 319 pages; illustrated. Price, $3.

The author has attempted the difficult task of covering a very broad subject in a limited space, with the result that while certain items are quite fully discussed, others have been slighted. Very properly the historical review has been confined to a short chapter. The chapters on "Thermodynamics" and on "Combustion and Explosion" are excellent, the latter taking up the variability of specific heats with temperature and quoting from the work of the British Association for the Investigation of Gaseous Explosions, as well as a number of individual experimenters. In view of their growing importance, too little space seems to have been devoted to the Diesel and the medium-compression oil engines; in fact as much stress appears to have been laid upon the marine gas plant as upon the marine Diesel. Much useful information is given on carburetors, ignition systems and gas-engine governing, and considerable space is devoted to the automobile engine. This is based largely, however, on English practice and does not include some of the later developments as exemplified in present American automobile practice. However, the many excellent features of the book outweigh its shortcomings, particularly in the principles underlying the design and working of the gas engine. As a textbook it should find favor, and certain of its chapters will afford a useful reference for the practicing engineer.

LOW GRADE FUEL IN EUROPE

Technical Paper 123 ("Notes on the Uses of Low-Grade Fuel in Europe," by R. H. Fernald; 37 pages, 4 plates, 4 figures) is available for free distribution from the Department of the Interior, Bureau of Mines. Applications should be addressed to the Director of the Bureau of Mines, Washington, D. C.

BOOKS RECEIVED

HOW TO MAKE A TRANSFORMER FOR LOW PRESSURES. By Prof. F. E. Austin, Hanover, N. H. Published by the author. Second edition; cloth; 17 pages; 4¾x7¼ in.; illustrated. Price, 40c.

THE GASOLINE AUTOMOBILE. By George W. Hobbs and Benj. G. Elliott. McGraw-Hill Book Co., Inc., New York. Cloth; 6x9¼ in.; 259 pages; 253 illustrations. Price, $2.

ENGINEERING THERMODYNAMICS. By James A. Moyer and James P. Calderwood. John Wiley & Sons, New York. Cloth; size, 5¾x9¼ in.; 203 pages; 70 illustrations; tables. Price, $2.

WATER POWER ENGINEERING. By Daniel W. Mead. McGraw-Hill Book Co., Inc., New York. Cloth; 6x9¼ in.; 843 pages; 437 illustrations; 101 tables. Price, $5.

MECHANICAL EQUIPMENT OF FEDERAL BUILDINGS. By Nelson S. Thompson. Heating and Ventilating Magazine Co., New York. Cloth; 6x9¼ in.; 402 pages; tables; plates. Price, $3.

INVENTIONS AND PATENTS. By Philip E. Edelman. D. Van Nostrand Co., New York. Cloth; 5¼x8 in.; 288 pages. Price, $1.50.

LOCOMOTIVE OPERATION AND TRAIN CONTROL. By Arthur Julius Wood. McGraw-Hill Book Co., Inc., New York. Cloth; 6¼x9¼ in.; 117 illustrations; 33 tables. Price, $3.

FORD METHODS AND THE FORD SHOPS. By Horace L. Arnold and Fay L. Faurote. The Engineering Magazine Co., New York. Cloth; 7x10¼ in.; copiously illustrated. Price, $5.

Handling Boilers to Prevent Corrosion and Scale*

By Allen H. Babcock†

SYNOPSIS—A thorough account of the use of the Navy boiler compound as used by the Southern Pacific Co., California. The percentages of the constituents of the compound are given, as well as those of the solutions and indicators used in testing the treated water from the boiler. Excerpts from the discussion of the paper also are given.

It seems from all that can be ascertained at present that there is a method of handling boilers with a compound applicable to any water under any conditions of steaming, without a material change in the formula. The only requirement is that the boilers must be treated individually; it is not enough to treat a battery, or to treat the feedwater going into the boilers in general.

The first application by the author of this method was made at the Fruitvale power station of the Southern Pacific Co., the boiler equipment of which consists of 12 water-tube boilers, each of 645 hp. The method is in no respect original with the author.

The first inspection of the boilers of the Fruitvale plant showed that serious corrosion began a short time after the plant was started, although the boilers were not on regular load. The ordinary remedial measures were ineffective. Bearing in mind that the plant was put in service to haul trains in the fall of 1911, it is significant that by June, 1912, the feed elements of the boilers were all in a serious condition. With a total of 3,360 tubes in all boilers, 252 tubes were requisitioned for replacement during the first eight months of operation. By the end of July, 1912, the trouble was extending to the second row of tubes, and 250 more tubes were requisitioned to take care of the trouble. In September inspection showed that the drums were being attacked. In October boilers Nos. 1 and 3, after having been equipped with new tubes and placed in service in August and worked with water treated by the lime process, were found to be pitted worse than ever, and this was after the first serious effort to treat the water. In November, 1912, the piping was modified according to a plan sent by the manufacturers of the boiler, but in December of that year the inspection showed the pitting to be very severe, and in January, 1913, 300 more tubes were requisitioned. This made a total of 1,050 tubes in a year and a half, not counting about 90 put in by the manufacturers.

REPAIRS CHARGES EXCEEDINGLY HIGH

About this time began the use of a compound furnished by one of the best-known companies in the business. The result was apparently to transfer some of the trouble from the tubes to another part of the boiler where there had been no trouble before. A sediment of black mud formed a scale that caused blisters and tube failures at those points. In June inspection showed bad corrosion and pitting in all parts of the boiler, and 960 tubes were requisitioned. By October, 1913, the total work orders for boiler repairs on that plant amounted to $16,000, or nearly 12 per cent. of the first cost of the boiler plant. Three different special formulas for compounds submitted by the same chemical company had been used, but as things were going from bad to worse the use of the special compounds was discontinued.

In the fall of 1913, with a fine steam plant in a critical condition, 1,160 tubes out of 3,360 had been replaced and there was no relief in sight. Another expert was called in, who began by suggesting the conventional methods of zincs and paints, and that perhaps electrolysis was to blame, although everything had been kept carefully insulated. The result was no better than before.

About that time the author was handed the August, 1912, number of the "Journal of the American Society of Naval Engineers," which gave an account, by Frank Lyon, lieutenant-commander, United States Navy, of what seemed to be a highly significant development in boiler-trouble treatment.[1] In the course of his article, Commander Lyon said: "The writer has no hesitancy in saying that any boiler, using any water, can be kept from corrosion for any length of time."

The result of Commander Lyon's investigations was the development of the Navy Standard Boiler Compound as described later. This compound is composed of sodium carbonate, trisodium phosphate, starch and tannic acid. The sodium carbonate takes care of any chemical reactions and renders the solution noncorrosive. The tannic acid and starch are added to prevent the formation of scale, the action being to hold the impurities in suspension in a colloidal state. The trisodium phosphate prevents the rise of the surface tension of the solution and consequent priming caused by the impurities in the water and by the application of the other ingredients in the compound. In using this compound to prevent corrosion a sufficient quantity must be added to each boiler to render the alkaline strength of the water in the boiler 3 per cent. of normal or above.

The compound may be purchased from the government contractor for about one-half the cost of the ordinary compounds.

BOILER-TUBE REPLACEMENTS FEW

On Mar. 4, 1914, the first boiler was placed under treatment with the Standard Navy compound. By Mar. 26 it was in use in all of the boilers. As illustrating the results, the record of tube replacements month by mohth is most significant. In 1912, 690 tubes were replaced; 858 in 1913. In January and February of 1914 there were 229 tubes replaced in the two months, or at the rate of 1,374 a year. The treatment, as stated, was begun on Mar. 4, and was in all the boilers on the 26th. Thence the record stands: In February, 171 tubes replaced; March, 24; April, 15; May, 2; and from May, 1914, to June, 1915 (date of writing), not one has been replaced for failures. There have been 13 tubes replaced since May, 1914, but all because they had to be taken out to get at something else, or by reason of obvious defects.

In 1912 the method cost in labor and material $5,790; in 1913, $10,256; in the first six months of 1914, it was $1,579, and since then the expense will hardly come to a hundred dollars a month for everything considered; that is, the ordinary wear and tear of the plant, washing of boilers, etc. In addition to this, extra labor in the plant (made necessary by the failing tubes) to the extent of $181 a month has been discharged. The treatment as practiced there costs about $80 a month, depending upon the amount of compound used. There is no scale in these boilers. Below the water line they show clean black iron; above, a thin coating like whitewash.

The first two months' operation at the Fruitvale power station with the Navy compound in use showed such satisfactory results that the management ordered a trial of the method on probably one of the worst locomotive-water districts in the company's service, namely, that part of the San Joaquin Division between Bakersfield and Mojave, known generally as the Tehachapi Pass. R. S. Twogood, assistant engineer in the office of the consulting electrical engineer, was detailed on this work, and for nearly a year he has given practically his entire time to this demonstration. The following is an abstract of his contribution to the discussion at the December (1914) meeting of the San Francisco Section of the society, when this subject came up for a general discussion:

FAVORABLE RESULTS WITH COMPOUND

On July 21, 1915, a compound test was started on a freight Mallet locomotive. The locomotive was just out of shop; it had a new set of flues and was free from scale, with the exception of a thin deposit on the crown-sheet and crown and stay-bolts that were not removed during back-shopping (general overhauling). The engine was left in chain-gang service (handled by many different crews).

At first an effort was made to carry the alkalinity at 3 per cent., but so far the best results have been from 0.5 to 0.7 per cent. normal alkalinity. Several things in the design of the locomotive, especially the Mallet, contribute to this result: A very small steam space and steam dome; no perforated dry pipe to collect steam; constant surging of the water due to the motion of the locomotive; sudden opening of the throttle and consequent great demand for steam, which reduces the

*Presented at the December, 1915, meeting of the American Society of Mechanical Engineers.

†Consulting electrical engineer, Southern Pacific Co.

[1]Navy Department, Washington, D. C. Postpaid, $1.30. Reprints of the article are also available.

pressure on the surface of the water under the throttle and causes it to rise and pass over into the steam pipes. Also, the water used for locomotive purposes in this district contains a large amount of solid matter which would tend to cause priming.

One point constantly in mind was to find some treatment in which one man could be made responsible, without having to depend on the engineers and firemen. This means that the boiler must be treated at engine turning points.

The water from Bakersfield to Mojave averages about 3 lb. of scale-forming matter per thousand gallons. A Mallet locomotive in a helper trip from Bakersfield to the Summit and return will use from 30,000 to 35,000 gal. of water, which means about 100 lb. of scale per helper trip. With the present method of treating, 20 lb. of compound are pumped into the boiler before leaving Bakersfield yards. This gives an alkalinity of about 0.6 per cent. and as this percentage remains approximately constant between engine turning points, it is possible to treat the boiler for an entire trip before it leaves the roundhouse.

PRECIPITATE SHOULD BE LARGE AND FLAKY

If too little compound is used the precipitate is fine and does not settle readily; but when the amount is sufficient the precipitate is large and flaky and settles rapidly. This makes it easy to clear the boiler of some of the solid matter by blowing down after the engine has been standing on the siding a few minutes awaiting passing trains.

Present practice is to wash the boiler every second trip. A large percentage of the solid matter runs out with the water while draining the boiler, and the rest is easily washed out. The solid matter has no tendency to cake, but will remain indefinitely in the form of a soft brown mud. It must be borne in mind that the frequency of washing is a function of the amount of solid matter in the water and the amount of water used.

Prevention of corrosion and scale formation was the main endeavor, and yet another result was obtained, just as important. No boiler troubles were encountered during the first four months of the test, and then the record was broken by only a minor leak, a record that gives some idea of the importance of keeping the boiler free from scale and thus preventing the high and uneven temperatures in the steel which cause the opening up of joints.

Foaming and priming became so bad in one of the passenger locomotives that the water in the glass rose as much as 8 in. when the throttle was open. No compound of any kind had been used in this boiler. Six pounds of trisodium phosphate (no compound) was then put in the boiler through the injector just before the engine left the roundhouse for each trip. There has been no foaming on this locomotive since.

During the last month the use of this compound has been extended to all freight Mallets (seven) operating out of Bakersfield. Some of these had been in service for several months, and large quantities of scale had formed. The cutting of this scale made very dirty boilers, causing frequent blowing and boiler washing. After two or three weeks, scale from ⅛ in. to ⅜ in. thick came off in large quantities, which proves that the compound will cut the old scale, but this action causes such dirty boilers that such procedure cannot be recommended.

The Associated Pipe Line Co. operates an oil-pipe line from the oil fields in the southern end of the San Joaquin Valley to tidewater near San Francisco. On this pipe line are 30 steam pumping stations equipped, some with three and some with four 250-hp. water-tube boilers. The feed water is of practically every known grade from good to very poor, and nearly every known type of boiler compound has been used from time to time in the worst of these stations. E. B. Partridge, Jr., superintendent of the pumping plants in the fields, came to Fruitvale power station for a study of the method. He began his investigation in the most skeptical frame of mind, and he introduced the compound first into a station where, as he said, it could do the least harm. Eight months later, at the December meeting of the San Francisco Section of the society, where the subject was discussed, he gave an account of his experience, which is here briefly summarized:

WATER WITH 230 GRAINS PER GALLON

In the 30 different pumping stations there were 30 different kinds of water, with a solid content running from 6 to 230 grains per gallon. In the first station, a three months' trial of the compound showed that a turbine tube cleaner was no longer necessary, because the boiler was readily washed out and cleaning would not be required oftener than every three months.

These results were confirmed at the next station where the compound was tried. It was then introduced in a station that most of the feed-water experts in the state had turned down as impossible. The water carries 230 grains to the gallon. In these boilers 2½-in. extra-heavy boiler blowoff nipples corroded away in from three to four months and 3-in. extra-heavy feed-water lines pitted through in the same time. Nearly every known variety of boiler trouble had been experienced at this plant, but the Navy compound eliminated corrosion and precipitated the solids in a soft slushy form easily washed out. Owing to the unusually large quantity of solid matter in the water, however, it was necessary to blow the boilers every hour and to clean every 10 days.

At another station where corrosion similar to that in the Fruitvale boilers had been experienced from the start and all kinds of compounds had failed to relieve the trouble, the Navy compound was introduced. Up to that time they had used No. 9 gage seamless tubes in the bottom boiler rows and No. 10 gage special spellerized tubes in the upper rows, but none of them lasted more than three months. Feed lines, blowoff pipe lines, boiler drums and headers, together with the tubes, were all affected by corrosion.

The following supplement is by Fred E. Geibel, assistant to Mr. Babcock, the author:

The water used for boiler purposes at the Fruitvale power station comes from two bored wells driven on the inside of the station near the north wall. The chemical analysis of the water is as follows:

	Grains per Gal.
Silica	0.932
Oxides, iron and aluminum	0.245
Carbonate lime	3.023
Nitrate lime	2.624
Sulphate lime	1.082
Carbonate magnesium	5.667
Chloride magnesium	1.769
Sodium and potassium chlorides	5.863
Loss, etc.	0.169
	21.374
Total incrustating solids	15.342

or 2.19 lb. per thousand gal.

In the original installation the feed water was introduced into the upper or economizer section of each boiler, having been partly heated before being discharged into the section. Operating in this way, it was practically impossible to keep tubes in the upper sections.

Later the feed-water connections were removed from the economizer sections and the water was fed directly into the drums at the front end, the feed pipe being run into the drum for a distance of about four feet. Two months' operation in this way showed serious corrosion in the bottom of the drums and practically the entire destruction of the internal portions of the feed pipe.

POTENTIAL DIFFERENCE DEPENDED ON FEED

Corrosion by stray currents from the railway system was suspected. To detect the presence of any such currents in the boiler, a copper terminal, or electrode, was placed through the shell of the boiler into the water, but insulated from the shell. A recording millivoltmeter connected between this terminal and the boiler shell or feed-water connection would indicate the presence of a potential difference, and it was expected that if the curve drawn by the voltmeter followed approximately the load curve of the station, it would show that the cause of corrosion was undoubtedly stray electric current from the railway system.

It was found that a small difference of potential did exist, but the curve drawn by the meter, instead of following the load curve of the station, was directly dependent on the boiler taking feed water. The voltmeter reached a maximum value, which was constant as long as the boiler was being fed. Closing the feed valve reduced the potential to practically zero, but as soon as it was opened the voltmeter would again indicate the maximum value. This led to the conclusion that the potential difference was due either to the temperature or to the chemical characteristics of the feed water. Other experiments, therefore, were started with a copper-iron couple in samples of water from the wells, before and after treating, and from the boilers, condensers and hotwells. Taking into account the varying contact-resistance between the electrodes and the water, the potential differences obtained with the several samples did not differ materially. With all the samples, however, the maximum difference of potential was obtained at temperatures between 170 and 190 deg. F.

While Mr. Babcock had seen the paper by Mr. Lyon describing similar tests and was watching results, he purposely allowed these tests to be carried on in ignorance of the paper. At the completion of these electrical tests the results were found to be practically identical with those described by Mr. Lyon.

In this method of boiler treatment it will be noticed that each individual boiler must be considered and the water in each boiler be kept above the prescribed concentration. At Fruitvale power station samples of the boiler waters are taken each morning. Simple tests are made to determine the alkalinity of the water and chlorine, or salt content. Any boilers low in alkalinity are treated with sufficient compound, pumped into the boiler, to bring the alkalinity up to the required point. Any boilers high in salt are blown down to rid them of the salt and then compound added to build up the alkalinity, if necessary. The boilers are arranged with suitable connections, and a portable pumping outfit has been provided for pumping compound directly into any particular boiler.

Shortly after beginning the high alkalinity in the boilers serious trouble arose with the manhole gaskets blowing out. It was thought that the strong alkaline solution was eating out the gaskets, which were of asbestos. It soon developed, however, that not only were the manhole covers slightly warped, but the surfaces next to the gaskets were coated in spots with iron rust. The action of the compound was to eat away this rust and a leak was started, resulting in the eroding and blowing away of the gasket. The truing of the manhole covers and cleaning of the surfaces eliminated this trouble. This action may also be noticed in old boilers where the seams are rusty. With the first application of the compound the rust is eaten away and leaks are started.

There was also some trouble with corroding of the brass check valves in the tube elements of the boilers. This, however, was expected, and at the time the treatment was begun malleable check valves had been ordered and have since replaced the brass ones.

WHEN TO BLOW OFF TREATED BOILERS

The amount of compound consumed per day is merely the amount required to take care of the chemical reactions in the makeup water, the water in the boilers having once been made the proper alkaline strength. If too little compound is used per day the alkalinity of the boilers will fall off, and if too much is used the alkalinity will gradually build up, as after the chemical reactions are taken care of any excess of compound begins to raise the alkalinity. Blowing-off reduces the alkalinity of the boiler, as some of the excess compound is blown out. This must be made up by the addition of more compound. Therefore, boilers should be blown off as little as possible and the frequency is dependent on the amount of impurities in the makeup water. The present practice at Fruitvale is a short blow every other day.

One important difference in this method of boiler-water treatment, and the commonly accepted theory as regards boiler waters, is the high alkalinity carried in the boiler. It

has been commonly considered that a boiler water high in alkalinity, or sodium content, has a decided tendency to prime. This is probably true if no anti-priming substance, such as trisodium phosphate, is added. However, while it was not known or expected by the boiler attendants, tests on the boiler waters at some plants have shown as high as 22 per cent .normal alkalinity. With this Standard Navy Boiler Compound it has been found that the tendency to prime is more a function of the solid matter in suspension than the per cent. of alkalinity of the water.

In stationary plants undoubtedly the most efficient process is to bring down most of the scale by the use of chemicals in an open type feed-water heater and to supplement this treatment with a compound in the boiler. The Navy compound cannot be used for this outside treatment, as the compound holds the scale in suspension. The most common chemical used for this purpose is soda ash. This outside treatment cannot be used with locomotives and is not always possible at stationary plants.

The ingredients of the Navy compound are intimately united by thorough digestion, dried, finely powdered and well mixed. They are readily soluble in water. The compound must show on analysis at least 76 per cent. of anhydrous sodium carbonate (Na_2CO_3), 10 per cent. of trisodium phosphate ($Na_3PO_4.12H_2O$), 1 per cent. of dextrine or starch, and sufficient cutch to yield at least 2 per cent. of tannic acid, the remainder to consist of water and only such impurities as are common to the ingredients.

MAKING THE SOLUTIONS AND INDICATORS

The Navy compound is in the form of a dry powder. It is easily dissolved in warm water, but should be boiled with a steam jet for 30 min. or more to digest the tannin thoroughly. Ordinarily this solution is fed continuously into the hotwell or feed-water line in quantity just sufficient to take care of the chemical reactions, or to render the water neutral. When the boilers are run at high alkalinity, the excess of compound necessary to raise the alkalinity should be pumped directly into each boiler.

For testing the water in the boiler solutions and indicators made up as follows must be used:

Solution No. 1 is an N/2 normal solution of sulphuric acid. Take about 950 c.c. of distilled water and to it add slowly 24.5 grams of sulphuric acid (H_2SO_4) or 13.3 c.c. of acid of 1.84 specific gravity. (Never add water to the acid.) To the solution now add sufficient distilled water to make 1,000 c.c. of solution. To determine the acid strength of the solution it should be checked against the soda solution. A given quantity of the acid solution should exactly neutralize an equal quantity of the soda solution.

Solution No. 2 is a solution of nitrate of silver made by dissolving 41.01 grams of silver nitrate ($AgNO_3$) crystals in distilled water to make 1,000 c.c. of solution. Such solution when used with a 50 c.c. sample of water represents for each c.c. of solution used 10 grains of chlorine per gallon of water. If it is desired that the results be in terms of grains of sodium chloride (common salt), the solution should be mixed 24.85 grams silver nitrate per 1,000 c.c. of solution.

Indicator No. 1 is the neutrality indicator and is made by dissolving 1 gram of methyl orange powder and 5 grams of phenolphthalein powder in 500 c.c. of alcohol and adding enough distilled water to make 1,000 c.c. of solution.

Indicator No. 2 is for the chlorine or salt test and is made by dissolving a gram potassium chromate (K_2CrO_4) in distilled water to make 100 c.c. of solution.

In general, tests of boiler water show it to be alkaline, neutral or acid. An acid substance neutralizes an alkaline substance, and vice versa. Therefore, to determine the degree of alkalinity or acidity of a water the opposite substance is added until the neutral point is reached. The quantity of substance added to bring about the state of neutrality denotes, when reduced to proper terms, the degree of alkalinity or acidity.

TESTING THE TREATED FEED WATER

The state of alkalinity, neutrality or acidity is determined by the use of solutions which serve as indicators. A few drops of indicator No. 1 added to an alkaline solution will turn it a deep red. If added to an acid solution the color will be pink. If the solution is neutral the color will be a faint yellow.

The standard boiler-water test outfit contains solutions 1 and 2; two indicators similarly numbered; one small bottle of soda solution; one dish; one stirring rod; one 50-c.c. measuring flask, and two burettes numbered 1 and 2. The burettes are graduated from 0 to 25 c.c. in 0.1 c.c. and are used to determine the quantity of standard solution used.

To make an alkalinity test, draw off a sample of water from the boiler into a vessel which has just previously been washed out with water from the same boiler. Allow this water to cool to about room temperature. Fill burette No. 1 with solution No. 1. Open the pet-cock at the bottom of the burette and draw off a few drops of the solution until all air bubbles have been expelled from the lower end of the burette and it is filled to the tip with solution when the cock is closed. Measure off 50 c.c. of the sample of boiler water, using the 50-c.c. flask, and pour it into the dish. Both the flask and dish should be just previously washed out with other water from the same sample. The sample used should be clear and contain only such impurities as remain in solution. If the suspended matter does not readily settle out the sample should be filtered.

Add four drops of indicator No. 1 into the sample in the dish and the color of the sample should turn immediately to a deep red. Now read the graduation at the top of the solution in the burette No. 1; then from the pet-cock at the bottom drop solution No. 1 into the sample in the dish, stirring continuously with the glass rod until the sample turns clear, then yellow, then a faint pink. Close the pet-cock and read the graduation on the burette at the top of the solution. The difference between the two readings indicates the number of cubic centimeters of solution No. 1 required to neutralize the alkali in the sample. The strength of the solution is so proportioned that the number of cubic centimeters of solution used to neutralize the sample represents directly the degree of alkalinity in per cent. of a standard normal alkaline solution. Thus if 2.3 c.c. of solution is used, the alkalinity of the sample is said to be 2.3 per cent.

CHLORINE TEST SOMETIMES UNNECESSARY

The foregoing instructions require that the solution be added until the sample turns a faint pink. This indicates that the alkali has been a little more than neutralized and the sample has become slightly acid. The error, however, will be negligible for the purpose of testing boiler water if the test is carefully made and the pet-cock closed at the instant that the faintest pink color is attained in the well-stirred sample. After the sample becomes clear the solution should be added drop by drop and the test conducted in a good light.

For a chlorine test, fill burette No. 2 with solution No. 2. Using the same sample used for the alkalinity test, add a drop or two of the soda solution to bring the sample back to a neutral or slightly alkaline condition. Add four drops of indicator No. 2. Now drop in solution from burette No. 2, stirring continuously, until the sample turns from yellow to a reddish yellow throughout. The number of cubic centimeters of solution used multiplied by 10 represents the number of grains of chlorine per gallon of water. That is, if 2.2 c.c. of solution is used it means that the water contains 22 grains of chlorine per gallon. If the solution is added until the sample is a deep red, erroneous results will be derived. The stopcock on the burette should be closed as soon as the change in color from yellow to reddish yellow occurs in the well-stirred sample.

Where boilers are blown down regularly the chlorine test may be omitted, as the amount of chlorine does not reach a dangerous point. At plants running condensing the chlorine should never be allowed to run higher than 500 grains per gallon. Blowing-off decreases the chlorine content.

Keep the dish, measuring flask and stirring rod clean. Never pour standard solutions from the burette back into the bottles. When a fresh supply of standard solutions is received, pour out all of the old solution and rinse the bottles and burettes several times with distilled water. On reading the height of liquids in the flask or burettes always read from the bottom of the meniscus.

The soda solution is an N/2 normal solution of caustic soda made by dissolving 20 grams of pure caustic soda (NaOH) in distilled water to make 1,000 c.c. of solution.

SUPPLEMENT BY MR. BABCOCK

The use of the Navy compound was discussed in a preliminary way at the December meeting of the San Francisco Section of the society. Later it was stated to the author that it would be well to go slow with reference to the use of the compound, because some vessels had experienced such serious damage to their boilers as to cast discredit upon its use. The statement claimed that evidence has been accumulating to show that under certain circumstances the use of sodium carbonate or sodium hydrate results in making steel brittle and in failure of the boiler joints by cracks. At present it is impossible to state correctly why the action occurs, but it is possible to name the circumstances under which it is likely to occur.

The theory advanced as to the cause of the trouble is as follows: Sodium carbonate is always partly converted into sodium hydrate when in solution under boiler temperature, so that it makes no difference whether the carbonate is used in the beginning, or caustic soda, or both, sodium hydrate will always be present sooner or later. When either of these sub-

stances is used for the treatment of scale, no trouble from the cracking of the steel is likely to occur, because they react with the scale and there is little or no excess hydrate. Where cracking has occurred it has always been true that free hydrate has been present in the boilers in the absence of sulphate; so that we may feel warranted in saying that whenever sodium carbonate or sodium hydrate is introduced into a boiler in the absence of substances reacting with them, brittleness will sooner or later result. Cases have been known in which the brittleness approaches that of cement of the same thickness as the plate. It occurs only in the seam of the boiler, either because the joints are at higher stresses than the rest of the plate, or because the joints are the only places in which this solution can concentrate, and it is known that unconcentrated solution does not attack steel. The cracks that result are distinguished from ordinary forms of cracking by the following characteristics: They are more fully developed at the surfaces of the contact of the joints than at other surfaces, so that a crack at a rivet hole will often measure ¾ in. on the contact surface of a ½-in. plate without showing on the other surface; in other words, the surface of the crack itself is usually triangular, with the base of the triangle on the contact surface. The cracks usually originate at the rivet holes and show scarcely any tendency to follow the lines of stress. Running from adjacent rivet holes, two cracks will often pass each other and after passing, join, leaving an island in the plate. They change their direction sharply and often, to an extent of 90 deg.; they are always unaccompanied by any elongation of the plate; and finally, they are always, of course, below the water line.

THE COMPOUND STILL USED IN NAVY

The statement cited many cases where such defective plates have been noticed. Among others were named the boilers of the United States torpedo boat "Aylwin," wherein occurred a fracture of one drum, and cracking of one or more drums of three boilers out of four; also, the United States coast guard cutter "Unalga," where a cracking of one drum out of two in a period of operation of about 14 months was noticed. The statement concluded by a note to the effect that in the case of the coast guard service, an order had been issued discontinuing the use of the navy compound.

Investigation has shown that the use of the compound has not been discontinued in the navy, but the compound is ordinarily used only in sufficient quantity to maintain the water at a low alkaline strength, not above ½ of 1 per cent. of normal, the point at which corrosion changes in character from general or even corrosion to local or pitting. In a steaming boiler no difficulty is experienced in maintaining the alkaline strength of the water at or above 3 per cent. of normal; but naval boilers are idle during a large part of the time, and because the compound does not remain in solution in idle boilers, but settles to the bottom, the alkaline strength of the water in the upper part of the boiler frequently falls between the limits of 1 per cent. and 2.5 per cent. of normal, and the effect of this alkaline strength is to promote corrosion in its most dangerous form, namely, pitting.

Early experiments with the compound showed that good steel will corrode almost evenly over its wetted surface when placed in distilled water, and that as boiler compound is added to give the water a low alkaline strength, the rate of corrosion is somewhat decreased, but the character of the corrosion remains the same. Therefore low alkalinity inhibits all but a light general corrosion, which is so small that it may be disregarded.

Further, since the navy uses much distilled water, only small quantities of scale-forming substances are present in the boilers; therefore much compound is not required to prevent scale.

In the case of the "Aylwin's" boiler extensive investigation failed to show that its failure was due to the use of compound containing sodium carbonate or sodium hydroxide.

Any condition of design or construction that causes leaky seams that can be made tight only by excessive calking might possibly produce brittleness in the metal of the plate.

It may be here stated that the White-Forster boiler installed in the "Aylwin" class has D-shaped water drums, similar to the Yarrow type. In practice, it was found impossible to keep the seams of the White-Forster boiler tight, owing to the tendency of the drum to assume a circular shape under pressure. The manufacturers of this boiler have since corrected this by placing struts in these drums across the long diameter. It is also understood that similar trouble has not been experienced with Yarrow boilers.

With reference to the "Unalga" as another vessel having had trouble of a similar nature, not enough is known at present upon which to venture a statement as to the cause of failure. It is known, however, that the cracks in the steam drum plates of these boilers are similar to those observed in the "Aylwin's" lower drum plates.

Mr. Giebel stated in the discussion that during the experiments corrosion was most rapid with the water at a temperature of 190 deg. F., and that the results with the boilers in service checked well with this. Walter M. McFarland declared that "almost all the statements" in the paper were "grossly inaccurate," but he failed to be as specific as one would expect after such an assertion.

George H. Gibson believed it was a step backward to treat the water inside of the boiler, stating that it is much better to treat the water at 170 to 180 deg., for then the reactions are instantaneous and the precipitate formed is coarse and settles rapidly. Mr. Gibson also mentioned the necessity for removing the sludge from the boiler to prevent foreign substance being carried over into the superheater and to the turbine blades, and stated that such removal is doubtful where the precipitation occurs in the boiler, as advocated in the paper.

William Kent wanted information that would enable members to buy the chemicals and make the compound. Mr. Giebel stated that owing to the digesting process a special machine was required in its preparation, and that therefore it was cheapest to buy it mixed.

Mr. Giebel mentioned reports of damage to boiler steel due to the action of concentrated sodium carbonate solutions, and, commenting on this, E. N. Trump said that he had conducted many experiments to determine if the carbonate of soda is responsible for the cracking of the steel and further stated that there is no evidence that it is responsible.

J. E. Walsh explained the terms "chain gang" and "back shopping" as applied in the paper to locomotives. "Chain gang" is used to designate a crew that does not operate any one locomotive many trips. The use of the term in the paper infers therefore that the locomotive metioned was subjected to rough usage. "Back-shopping" refers to the difference in ordinary repairs done from time to time in the roundhouse and putting the locomotive in the "back shop," where it received a general dismantling and overhauling.

In closing, Mr. Giebel stated that the specifications for the Navy compound as given in the paper are the same as those submitted to the government contractor and the chemical company for mixing the compound. On question by William Kent, Walter M. McFarland explained that a 3-per cent. normal alkaline solution was 40 grams of caustic soda per liter of water. [Forty grams per liter for a 3-per cent. normal solution is probably the stenographer's error; 40 grams per liter is a normal solution, and 3 per cent. normal is 1.2 grams per liter, or very nearly 1 lb. per 100 gal. of water treated.—Editor.]

Not a Uniflow Engine

Investigation of a report which has been current that an accident had happened to a uniflow engine at Skaneateles, N. Y., revealed the facts that it was not a uniflow engine that was involved, but a twin variable-speed counterflow engine built by Skinner, of Erie, who also builds uniflow engines, and that the accident was due not to the engine, but to the jackshaft that it drove.

One of the boxes immediately alongside of the driven pulley had an old crack cutting it almost in two. This box evidently gave way, the four bolts holding it being bent and sheared and the concrete around the bolts having been worn away by the working of the bolts therein. It seems evident that when this bearing gave way the shaft was bent and the rope drive went to pieces wrecking the governor and allowing the engine to race until it burst its flywheel. The engine was little injured and was put into operation within a few days.

Panama-Pacific Exposition Awards—The awards at the Panama-Pacific International Exposition have not yet been made. The secretary has instructions not to give out the final decisions until a list in every department is completed, and it is not likely that the diplomas and medals will be received from Washington and officially awarded before the end of the year.

Correction: Bends for Pipe Line Expansion—In the article by W. L. Durand, page 786, issue of Dec. 7, 1915, a typographical error appears in the last line in the answer to the example given. The answer should be 70 in., as a use of the chart in solving the problem will indicate.

Decomposition of Ammonia*

By Prof. R. Plank

SYNOPSIS—The author agrees that explosions as they occur in the ammonia equipment of refrigeration plants are instantaneous and not the result of slow combustion of the ammonia, this gas being combustible only in pure oxygen. The decomposition of ammonia is hindered by a lowering of the temperature and an increase in pressure. Decomposition increases rapidly between 500 and 900 deg. F. Catalytic action also is a factor, and the impact of the gas during compression, especially in high-speed machines, greatly aids decomposition. After decomposition in the compressor and when the gases are in the condenser and cooled to the liquefaction temperature, much ammonia is recovered.

[The article is necessarily technical from the viewpoint of the average engineer because much of it deals with the decomposition of ammonia according to the theory of chemical equilibrium, also known as the statics of gas reaction. Much of this technical and chemical matter, which is used to lead up to the conclusions, is omitted in this abstract, and those parts of the article most useful to the engineer are retained.—Editor.]

The author agrees with the opinion generally held that ammonia explosions are instantaneous explosions and that there is not slow combustion of the ammonia; ammonia being combustible only in pure oxygen.

The decomposition of ammonia proceeds according to the equation

$$2\,NH_3 = N_2 + 3\,H_2 \qquad (1)$$

that is, by the complete decomposition of two parts of NH_3 by volume, one part by volume of N_2 and three parts by volume of H_2 result, doubling the total volume. With this reaction, as with every exothermic chemical reaction, is connected the generation of heat, the amount depending upon the temperature. In the production of ammonia from the elements, known as the synthetic method[1], which is becoming more widely adopted, a quantity of heat is liberated, and for the decomposition of the ammonia a like quantity of heat must be supplied. According to Thomsen and Berthelot, at ordinary room temperature the heat required for the decomposition of 2-kg.-molecules (34 kg. or 34 lb.) of ammonia is 24,000 C (large calories) or approximately 91,000 B.t.u. This quantity changes with the temperature and the varying specific heats of NH_3, H_2 and N_2, increases rapidly with increasing temperature, and at 850 deg. C. (1,562 deg. F) reaches 30,000 calories (approximately 119,000 B.t.u.).

It is known that high temperature favors the decomposition of ammonia. At any temperature and pressure the thermodynamic equilibrium demands the presence of a definite quantity of each of the three constituents, although they may be represented in exceedingly small quantities. This theory of chemical equilibrium, which is also known as the statics of gas reaction, is now understood and accepted as correct.

According to Nernst[2], the heat of disintegration of ammonia is the same in quantity as the heat of formation. Theoretically, the decomposed quantity of ammonia is inversely proportional to the square root of the pressure, but for reasons mentioned further on, the comparison between theory and test is possible only at high temperatures.

At every final temperature and every final pressure all three constituents of the chemical reaction—NH_3, N_2 and H_2—are represented in the mixture at temperatures below 0 deg. C. (32 deg. F.) especially at high pressures, and the quantity of ammonia decomposed is exceedingly small, while at temperatures above 700 deg. C. (1,292 deg. F.) there remains merely traces of ammonia. Long before this exact theory had been established, Ramsay and Young[3] had pointed out that the decomposition of the ammonia even at the highest temperatures was never complete. At the more recent tests by Perman and Atkinson, Jost, Haber and Le Rossignol, measurable quantities of ammonia were found even at temperatures as high as 1,100 deg. C. (2,012 deg. F.).

The decomposition of ammonia increases greatly between 100 and 300 deg. C. (212 and 572 deg. F.). Deductions based on the statical theory of chemical equilibrium will further be found to be greatly modified and improved by the consideration of the effect of kinetic conditions which, unfortunately, are as yet not entirely understood. One of the questions involved is the velocity of reaction and the catalytic action of solid bodies, such as metallic walls, with which the gases come in contact. But here, also, pressure and temperature qualitatively exert the same influence upon the decomposition, so that the equations arrived at so far still apply, but on a different scale.

In mechanical refrigeration we are concerned with the temperature range, including about —50 and +150 deg. C. (—58 and 302 deg. F.) at pressures of 1 to 14 atmospheres (14.7 to 206 lb.) absolute. The low pressures, 1 to 4 atmospheres (14.7 to 58.8 lb.) absolute, and temperatures of —50 to 0 deg. C. (—58 to 32 deg. F.) apply to the suction side of ammonia compressors, while the higher pressures, 7 to 14 atmospheres (103 to 206 lb.) absolute, and temperatures 30 to 150 deg. C. (80 to 302 deg. F.) apply to the discharge, or high-pressure, side of the system. It is fortunate, so far as decomposition of ammonia is concerned, that the high temperatures are associated with high pressures, as theory shows that on the suction side the decomposition, even under favorable conditions, will not exceed 1 per cent., whereas, on the discharge side, it may proceed much farther.

DECOMPOSITION IN COMPRESSION SYSTEM

There appears, with dry compression under most favorable conditions, a decomposition amounting to about 5 per cent., which under extreme conditions increases to 25 per cent., compared with the condition of equilibrium.

But on the way to the condenser and in the condenser, the gases become cooled to the liquefaction temperature, whereby a great amount of the ammonia is recovered. Thus at a condenser pressure of 9 atmospheres (132 lb.), the saturated vapor of 21 deg. C. (69.8 deg. F.) contains again 99 per cent. NH_3. The condenser pressure is of scarcely any influence in this connection, because it is offset by the counter action of the condensing temperature.

Under very high condenser pressures the quantity remaining decomposed is a trifle greater than at lower pressures. Since this decomposed part consists of gases (H_2, N_2) difficult to liquefy, this part will not condense; it will be carried as ballast through the condenser and evaporator. But as the quantity does not exceed more than about 1 per cent., the loss is not serious. The decomposed gases may become dissolved largely in the liquid ammonia.

With wet compression the amount of ammonia decomposed during the compression is the less the lower the superheat at the end of compression. In the condenser and evaporator, however, there is no change.

So far we have concerned ourselves only with the chemical equilibrium of gas reaction, and have found that at temperatures in refrigerating machines, a perceptible quantity of ammonia should decompose into its elements. In the same way there ought to be formed ammonia at these temperatures from a mixture of $N_2 + 3\,H_2$. In contradistinction to this theory the test proves that there is neither a decomposition of the pure ammonia nor a formation of the same out of the elements at low temperatures, and that the condition of equilibrium is not reached in either case. The cause for this lies in the fact that the equilibrium is obtained exceedingly slowly at low temperatures, owing to the effect of the exceedingly inactive nitrogen[4]. Hence the velocity of reaction, here almost zero, increases rapidly as the temperature is increased. A mixture of $N_2 + 3\,H_2$ at room temperature is chemically

*Abstracted from an article in the July "Journal" of the American Society of Refrigerating Engineers and originally published in the "Zeitschrift für die gesammte Kalte-Industrie," Berlin, March and May, 1915.

*See also "Decomposition of Ammonia and Chances of Explosions," by F. L. Fairbanks, "Power," Nov. 23, 1915, p. 715.

[1]To date by far the greatest quantity of ammonia has been produced by the dry distillation of nitrogenous coal as a byproduct in the manufacture of illuminating gas.

[2]"Zeitschr. f. Elektrochemie," 16, 1910, p. 100.

[3]"Journal Chem. Soc.," 45, 1884, p. 88.

[4]In the production of oxide of nitrogen, NO, from air it is found that the nitrogen reacts very slowly even at 2,000 deg. C. (3,632 deg. F.).

indifferent, not because of the absence of chemical affinity, but because the velocity of reaction is exceedingly small. Physico-chemists do not doubt that, for example, a mixture of hydrogen and oxygen will at ordinary temperatures change gradually to water, but the quantities of water formed during the time available to the experimenters are not great enough to be measurable. Evidently the determination of the decomposition of gas mixture depends not only upon the equilibrium, but also upon the velocity with which this equilibrium is reached.

It has been found that in the case of different gas reactions there are certain solid bodies in the presence of which the velocity of reaction increases without these bodies suffering any chemical change. This phenomenon is known as catalysis. For example, a catalytic action is exerted by the walls of a vessel containing reacting gases. In the free gas space the velocity of reaction is always less than at the walls. Our knowledge of these catalytic gases is as yet incomplete.

We will briefly review previous investigations on the decomposition of ammonia as affected by kinetic conditions. To my knowledge Ramsay and Young (1884) were the first to investigate this subject. They operated in the temperature range of 500 deg. C. to 830 deg. C. (932 to 1,526 deg. F.) and proved that the decomposition of ammonia under the most favorable circumstances commenced but slightly below 500 deg. C. But today we are positive that for every temperature below 500 deg. C., there must be decomposition, which, however, escaped the observers within the short testing periods, because the velocity of reaction is so slow.

From laboratory experiments made, the conclusion would be reached that the decomposed quantities are too small to be of any influence in the working of the refrigerating machine. They would be, if it were not for another circumstance the exact influence of which is beyond calculation, but tends to accelerate the decomposition. We will revert to this farther on.

TEMPERATURE INFLUENCE ON CATALYSIS

The tests by Ramsay and Young proved that the decomposition of NH_3 progresses slower in porcelain than in iron tubes (iron being a better catalyser), but their tests with a glass tube showed a still slower decomposition, becoming noticeable only at 780 deg. C. (1,436 deg. F.). Evidently a glass surface effectively hinders the decomposition.

Perman and Atkinson[5] also made tests, working between temperatures of 677 and 1,111 deg. C. (approximately 1,250 and 2,000 deg. F.), using a reaction vessel made of porcelain. The quantity of decomposed ammonia was measured by the resulting pressure increase at constant volume (the decomposition doubles the volume at constant pressure). The investigators proved that the decomposition was accelerated by the presence of certain metals, such as mercury, iron and platinum. Their tests are difficult to interpret, because no two were made under comparative conditions. The one positive result that may be based upon these tests is the fact that the reaction in the main takes place at the surface of the solid bodies and not in the gas space. Each kind of solid catalyser causing a different reaction, the reaction within the mass of gas (that is, away from the walls of the vessel containing the gas), would necessarily be insignificant.

The tests by Perman and Atkinson have proved the accelerated action of certain metals upon the decomposition of ammonia, while the tests of Haber and Le Rossignol[6] showed that the formation of ammonia also was accelerated by the presence of metals, such as manganese, iron and others. Clearly, iron accelerates the approach to equilibrium in both directions. But all catalysers mentioned are effective only at high temperatures.

The slowness with which reaction proceeds at low temperatures appreciably modifies the purely statical observations. Qualitatively, the influence the temperature and pressure variations remain, but quantitatively, the low reaction velocities cause a considerable shifting of the resulting gas composition in the direction of low temperatures. This fact is of advantage in mechanical refrigeration, because a decomposition of the ammonia during compression would be accompanied by a corresponding increase in volume, and therefore an increase in power consumption; on the other hand, the refrigerating capacity is scarcely affected by the decomposition, even at the point of equilibrium, because of the cooling effect in the condenser, which allows at most 1 per cent. to remain decomposed.

The result now arrived at does not quite agree with practice, because cases are known where large quantities of hydrogen and nitrogen have been found in the mains of ammonia refrigerating machines.[7] The question is, how did this decomposition take place? No doubt in every case the compressors were operated with a high degree of superheat. Hence we must inquire what other influences outside of the catalyser might favor decomposition. These influences include:

1. Effect of heat (temperature increase).
2. Photo-chemical effects (radiation by short-waved chemically active rays).
3. Electro-chemical effects (cathode rays, quiet electrical discharge, Siemen's tubes, arc-light discharge)[8].
4. Mechanical impact (sudden compression).

Of the effects enumerated, only the first and the fourth apply in mechanical refrigeration. The exceedingly short time 0.2 to 0.05 sec.) available for the compression of the ammonia vapors, especially in high-speed machines, may greatly favor the decomposition of ammonia. The extent of the effect, however, cannot be calculated. At any rate, the rapid compression may be considered as equal to mechanical impact, and therefore the decomposition in the compressor cannot be compared with that obtained in laboratory vessels.

IMPACT OF GAS PROMOTES DECOMPOSITION

Acceleration of the decomposition by the compression impact appears to be the only possible explanation for the noticeable quantities of products of decomposition found. In refrigeration the decomposition is objectionable, because the quantities once decomposed are not recovered, because of the slow reaction velocity obtaining also in the formation of ammonia, even if their temperature by the action of the cooling water in the condenser remains unchanged. They reduce the refrigerating capacity and increase the power consumption until they are expelled from the system.

Wherever the condenser pressure is unduly high, as in cases of very low temperatures and unfavorable conditions of cooling water, and where with dry compression high temperatures of superheat are to be expected, it will be advisable to resort to means for ameliorating the decomposition. The following expedients are suggested:

1. Avoidance of high speed.
2. Abandonment of completely dry compression; adjusting of the feed valves in such manner that the temperature in the discharge pipe will be at most 80 to 100 deg. C. (176 to 212 deg. F.).
3. Effort to reduce to a minimum the time of exposure to high temperature. This may be accomplished by water-jacketing the discharge pipe at the compressor cylinder to promptly remove the superheat. A cylinder of sheet metal around the discharge pipe with cooling water flowing in opposite direction to the gas should meet the requirements.
4. Improving the catalytic action of the surfaces inclosing the hot gas. We have seen that iron favors the decomposition of ammonia, while glass hinders it. Therefore, it would seem to be good practice to line the discharge pipe in its hottest section with enamel or some similar coating. No such expedients can be applied in the compressor cylinder, but by proportioning diameter and stroke in such a way that a minimum of surface is obtained, an improvement will be gained also from the viewpoint of diminishing cylinder heating.

The author is of the opinion that in no case are the quantities of decomposed ammonia in the system sufficient to form, with the atmosphere, an explosive mixture. He holds that the explosions reported can only have occurred by great quantities of undecomposed ammonia escaping from the machine. In striking open lights these became sufficiently heated to cause high reaction velocities, thus causing a complete decomposition of the ammonia outside of the machine. The resulting great quantities of hydrogen becoming mixed with the oxygen of the air caused the explosions. Complete decomposition of the ammonia after escape into the atmosphere is accomplished much more readily than inside the machine, because of the low pressure.

The same condition holds when an open light is introduced into a compressor. The flame induces the decomposition, and therefore open flames should be prohibited in the neighborhood of ammonia machines.

The writer agrees with M. Krause, who is of the opinion that in the tests of Schlumberger and Piotrowski[9], the electrical spark caused local decomposition of the ammonia. The combustion of the hydrogen raised the temperature of the remaining mass of gas to that corresponding to high reaction velocities, effecting complete decomposition of the quantity.

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[5] "Proc. of the Royal Soc.," 74, 1905, p. 110.

[6] "Zeitschr. f. Elektrochemie," 19, 1913, p. 54.

[7] "Journal American Society of Refrigerating Engineers," May, 1915, p. 40.

[8] Regarding the electro-chemical equilibrium of ammonia, see especially Davies, "Zeitschr. f. Physik. Chemie," 64, 1908, p. 657.

[9] "Journal f. Gasbeleuchtung und Wasserversorgung," 1914, p. 941.

First Annual Convention A. A. E.

On Dec. 10 and 11 the American Association of Engineers held its first annual convention in the Hotel La Salle, Chicago. A great deal of enthusiasm was shown in the new work, and at the largest session, Saturday afternoon, the attendance was well up to 400. About half of these were members and the remainder engineers of the city, with a sprinkling of out-of-town engineers. It will be remembered that this organization was formed about seven months ago by some 300 Chicago engineers drawn from the various engineering departments of the City of Chicago, State and Federal Governments, as well as the large industrial enterprises employing engineers in the city, as, for example, the railroad, electric light and telephone companies. The association was originated principally for the purpose of bringing into closer relationship the employer of engineers, the employee and the public.

At the first session on Friday morning, H. S. Baker, assistant city engineer, tendered a welcome to the new association. W. D. Wilcox, president, delivered the opening address, which dealt principally with the aims and objects of the association. In the response F. H. Newell, professor of civil engineering at the University of Illinois, outlined the problems of the engineer from the welfare standpoint. He emphasized the idea that the society was in no wise antagonizing any other good welfare movement. but instead would stimulate and help existing organizations. He spoke at length on the duty of the society to the engineer, and suggested that younger men be chosen more often as officers. Professor Newell likened the material development of the age to a Frankenstein organism which threatens to destroy its creator, the engineer, unless the same type of mind be utilized to control it. In other words, he sounded a call to the engineer to participate in the larger civic affairs of the nation. The engineer will not get his due until he is willing to take his post in public affairs. At present there is not an engineer at Washington among the 400 Congressmen or the hundred Senators. The speaker did not approve of viewing imperfect public affairs from the outside. The engineers ought to get together to help upbuild with high ideals rather than to call attention to the defects and deficiencies of other organizations or of existing conditions. He believed in the enthusiasm which had been manifested in getting up the new association and in the broad sympathy of the men who had initiated the movement.

In a brief report the secretary, Arthur Kneisel, stated that since Sept. 15, when active clearing-house work had really started, more than 100 engineers had been put in touch with positions at no cost to the engineer or employer. The organization now numbers about 300, and at the Saturday afternoon session about 40 applications for membership were received. Chapters are in process of formation in 19 cities, including New York, Indianapolis, Minneapolis, St. Louis, Kansas City, Cleveland, Buffalo, Springfield, Ill., and Seattle. The morning session ended with a discussion on the unethical work of some engineers employed by selling companies that furnish free plans and engineering services.

BENEFITS OF COÖPERATIVE ORGANIZATION

At the afternoon session an interesting address by Garrison Babcock, on the benefits of coöperative organization, was followed by a lively discussion on the qualifications of members. The consensus of opinion seemed to be that each applicant should be put upon his own honor; that is, should prepare his own record, and if it was overdrawn, he himself would be the sufferer. The qualification commitee would investigate the record, and if it was found to be inaccurate the applicant would be refused membership. This had already occurred on two different occasions. The ritual was adopted at this session.

At the banquet in the evening 130 sat at table. Everett Jennings, counsel for the State Public Utilities Commission, gave a brief address, and a toast to the engineers' wives and families was delivered by Professor Newell.

At the morning session on Saturday, G. Willard Rich, a patent attorney, of Rochester, N. Y., delivered an interesting address on the "Relation of Patent Rights to the Engineer." He brought out the point that the firm that stole or misappropriated the patent rights of an employee often suffered more than the patentee. Frequently such injustice came back on the guilty parties.

A. H. Krom, an electrical engineer, of Springfield, Ill., outlined how chapters in the various cities might best be started. A luncheon club to begin with would do until enough members were secured to organize a chapter and hold meetings regularly. Twenty members are required before a charter can be secured.

The afternoon session, with an attendance of nearly 400, was the largest of all. H. M. Foster, of the Chicago Telephone Co., presented a two-roll scenario, interwoven with which was the engineering story of a telephone system, the purpose of which was to educate the public as to the engineering problems that must be solved in this work.

In his address on the "Economic Aspect of Engineering Pay," J. H. Prior, chief engineer of the Illinois Public Utilities Commission, demonstrated by diagram that the pay of the lowest "margin" man in an organization had a direct effect on that of the highest paid. He pictured the law of supply and demand and showed that the same results could be obtained in the case of free bargaining when both the engineer and the prospective employer had full knowledge of the conditions. The convention closed with an exemplification of the ritual. This was received with much applause and general satisfaction.

ENGINEERING AFFAIRS

Paterson, N. J., No. 2, N. A. S. E. held its annual banquet at Alpha Inn., Paterson, on Saturday evening, Dec. 18. The affair was attended by about one hundred members and guests, including representatives of the N. A. S. E. from a number of northern New Jersey associations. Among the invited guests were Mayor Robert H. Fordyce, Mayor-elect Amos H. Radcliffe, who is a member of No. 2, State Senator-elect Thomas F. McCran, and the Passaic County members-elect of the New Jersey Legislature, all of whom pledged their support of legislation providing for appropriate penalties for infractions of the state license laws.

Massasoit Association No. 2, N. A. S. E., on Tuesday evening, Nov. 7, tendered a banquet and reception to Walter Damon, national president. Mr. Damon is an old and active member of Massasoit Association. The Ladies' Auxiliary aided in making the reception a success. A home-made chicken dinner was served by the ladies and entertainment was given by Miss Grace Steer, John Benson, Billy Murray, of Jenkins Bros., and Jack Armour, of "Power." Mr. Damon was presented with a handsome silver service and Mrs. Damon a bouquet of flowers, the gifts of the engineers and the ladies respectively. Brief speeches of appreciation were made by the national president and his wife.

BUSINESS ITEMS

The Commonwealth Edison Co. of Chicago is said to be negotiating for designs for 50,000-kw. turbo-generator.

The business of R. F. Morse was recently incorporated and is now known as R. F. Morse Company, with offices at 86 Weybosset St., Providence, R. I.

The Union Electric Light and Power Co., of St. Louis, Mo., has just closed an order for a 20,000-kw. turbine and will install 10 large boilers to serve the unit.

The Homestead Valve Manufacturing Co., Pittsburgh, Penn., has been appointed Eastern representative of the Taylor Steam Specialty Co., Battle Creek, Mich., and will, in future handle the Taylor specialties in all territory east of the Ohio River.

"The Terry Turbine" is the title of a new bulletin just issued by The Terry Steam Turbine Co., Hartford, Conn., giving a general description of the various turbine applications, and dealing particularly with various kinds of high, low and mixed pressure turbines. Copies sent on application to the company.

The leading fiction article in "Everybody's" Magazine for December entitled "My First Concert" and announced as the first of a series of Boytime sketches "by a new 'Everybody's' writer" is from the pen of Carl I. Henrikson, advertising manager of the Chicago Pneumatic Tool Company, Chicago, Ill., and editor of the company's house organ "Ideal Power."

A beautiful catalog has just been published by the Quaker City Rubber Co., 629 Market St., Philadelphia, Penn. It is known as Catalog No. 17 and is mailed on request. 180 pages, well printed on highly coated paper, profusely illustrated, many of the illustrations in colors. It is in fact a handbook on sheet packing, rod packing, rubber belting, etc., that every power plant man should have.

The recent publication issued by The Wm. Powell Co., of Cincinnati, Ohio, is a 20-page booklet on their "White Star Valve." This book briefly, but completely, discusses the function of these valves, and illustrates in section the several types made by the Wm. Powell Co. It contains full information as to construction, operation, and prices. Requests for copies to the company, by mail, will be gladly acceded to.

Yarnall-Waring Co., Chestnut Hill, Philadelphia, Penn., has recently made sales of "Lea" V-notch recording liquid meters totaling 4,300,000 lb. per hour, a few of the notable sales being to the Atlantic Refining Co., Philadelphia, Penn.; American Smelting and Refining Co., Perth Amboy, N. J.; E. I. du Pont de Nemours Powder Co., Hopewell, Va., Carney's Pt., N. J., and Kenvil, N. J., and the Philadelphia Electric Co., Chester, Penn., and Philadelphia, Penn.